Pilot Test Work Plan

Southeast Rockford

Groundwater Site

Area 9/10

Rockford, Illinois

CERCLIS ID No. ILD9801000417

July 3, 2003

Prepared for:

HAMILTON SUNDSTRAND CORPORATION
4747 Harrison Avenue
Rockford, Illinois 61125

Submitted by:

SECOR

SECOR International Incorporated
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July 3, 2003

Mr. Russell Hart
Remedial Project Manager
United States Environmental Protection Agency
Region V
77 West Jackson Blvd
Mail Code SR-6J
Chicago, Illinois 60604-3590

RE: Pilot Test Work Plan and Associated Project Plan Addenda (QAPP, FSP)
Remedial Design
Area 9/10
Southeast Rockford Groundwater Contamination Superfund Site

Dear Mr. Hart:

On behalf of Hamilton Sundstrand Corporation (HS), SECOR International Incorporated (SECOR) is submitting the enclosed Pilot Test Work Plan and associated Project Plan addenda in support of the Remedial Design for Area 9/10 of the Southeast Rockford Groundwater Contamination Superfund Site in Rockford, Illinois. The documents consist of the Pilot Test Work Plan, the Quality Assurance Project Plan (QAPP) Addendum for the AS/SVE Pilot Test, and the Field Sampling Plan (FSP) Addendum for the AS/SVE Pilot Test. Each plan has been prepared to supplement the Remedial Design (RD) Work Plan dated February 26, 2003, as revised and approved by the United States Environmental Protection Agency (USEPA). An electronic copy of these documents has also been included on the enclosed compact disc.

We look forward to continuing to work with you on this effort. If you have any questions, please do not hesitate to call

Sincerely,
SECOR International Incorporated

David M. Curnock
David M. Curnock
Principal Scientist

Enclosures: Pilot Test Work Plan, QAPP, FSP
QAPP Addendum for the AS/SVE Pilot Test
FSP Addendum for the AS/SVE Pilot Test

cc: T. Turner, USEPA
S. Moyer, HS/UTC
E. Alletzhauser, UTC
T. Williams, IEPA
T. Ayers, IEPA

PTWPtms070303.doc

PILOT TEST WORK PLAN
Remedial Design
Area 9/10
Rockford, IL
SECOR Project No.: 13UN.02072.01.0001
July 3, 2003

Prepared for:

HAMILTON SUNDSTRAND CORPORATION
4747 Harrison Avenue
Rockford, Illinois 61125

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SECOR International Incorporated
446 Eisenhower Lane North
Lombard, Illinois 60148

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SECTION 1.0

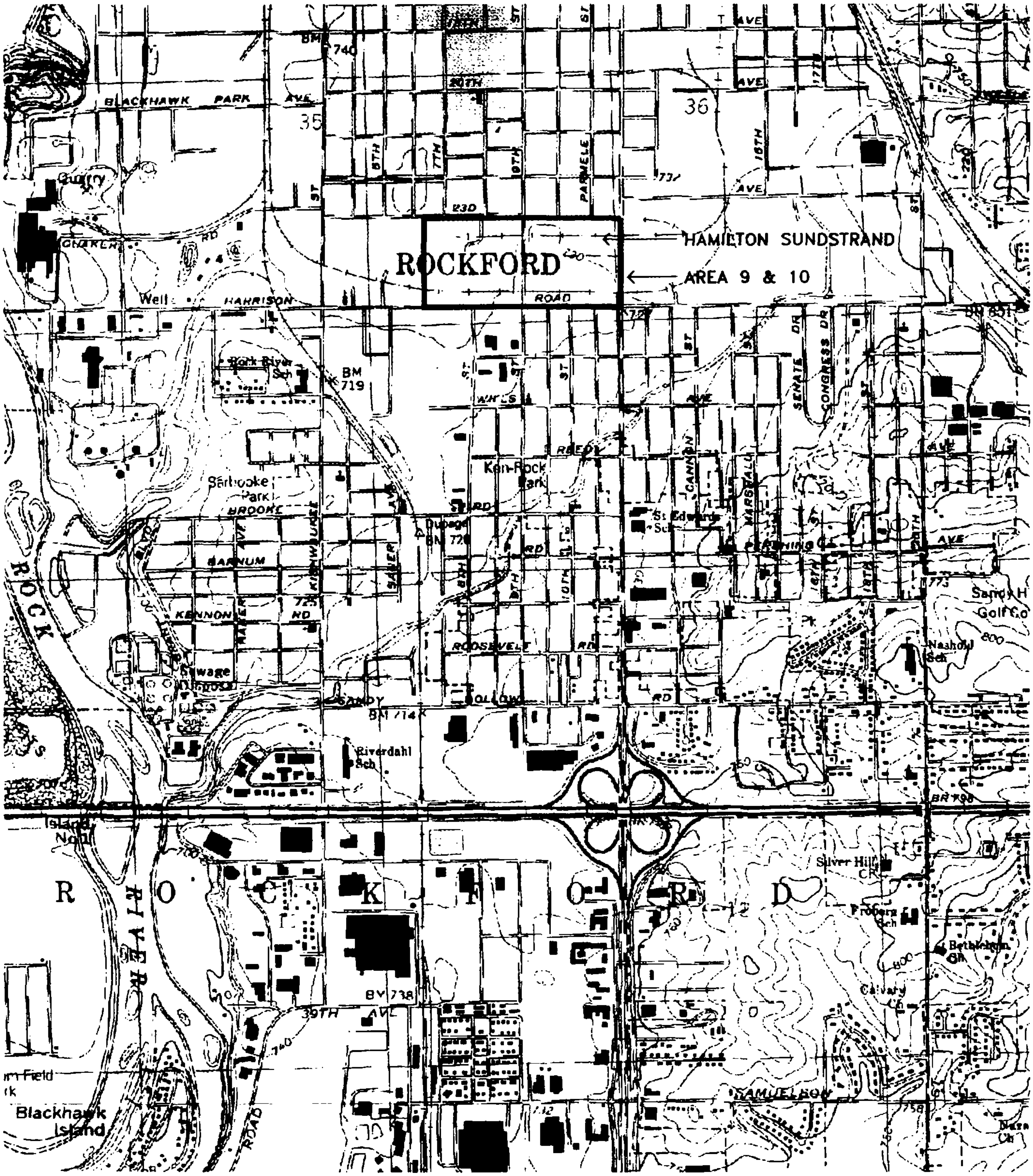
INTRODUCTION

This Pilot Test Work Plan (PTWP) presents the methodologies to be used for completion of Pilot Testing to support the completion of the remedial design for an Air Sparging/Soil Vapor Extraction/ (AS/SVE) system associated with the Area 9/10 portion of the Southeast Rockford Groundwater Contamination Superfund Site (SER site) located in the City of Rockford, Illinois (Figure 1). The term "Site" refers to Area 9/10, an industrial area in Rockford, Illinois, Winnebago County, Illinois, that is bounded by Eleventh Street on the east, Twenty-third Avenue on the north, Harrison Avenue on the south, and Sixth Street on the west. The Hamilton Sundstrand Corporation (HS) Plant #1 facility is located within Area 9/10 at 2421 Eleventh Street. Figure 2 depicts the Site layout. This PTWP provides a detailed description of Pilot Test objectives as well as the equipment, data collection methods, data analysis methods, and data interpretation procedures to be utilized during the implementation of the Pilot Test according to the RD Work Plan dated February 27, 2003 (Work Plan), as revised and approved by the U.S. Environmental Protection Agency (USEPA).

PILOT TEST OBJECTIVES

The objective of the Pilot Test is to collect and evaluate technical data necessary for the design and installation of a AS/SVE system to help meet the goals the Record of Decision (ROD) established for Area 9/10. The objectives of the Pilot Test are to obtain data on the following as it relates to SVE design:

- Vapor flow and vacuum induced in the subsurface at the extraction well and at monitoring wells;
- Site-specific relationship between vapor flow rate and vacuum induced;
- Effects of SVE on the water table;
- Spatial geometry of vacuum and air flow induced as a result of SVE;
- Site conditions such as preferential pathways, utility conduits, or surface paving that will impact SVE operation;
- Volume of condensate and sediment extracted as a byproduct of the SVE process;



0 1000 2000 3000 4000 5000

SCALE IN FEET

NORTH

REFERENCE: USGS 7.5 MINUTE QUADRANGLE: ROCKFORD SOUTH, IL

DESIGNED BY: GLH	SECOR	SITE LOCATION MAP HAMILTON SUNDSTRAND AREA 9/10 ROCKFORD, ILLINOIS
DRAWN BY: GLH		
APPROVED BY: JGH		
DATE: 6-17-03		JOB NO. 13UN.02072.00 FIGURE 1

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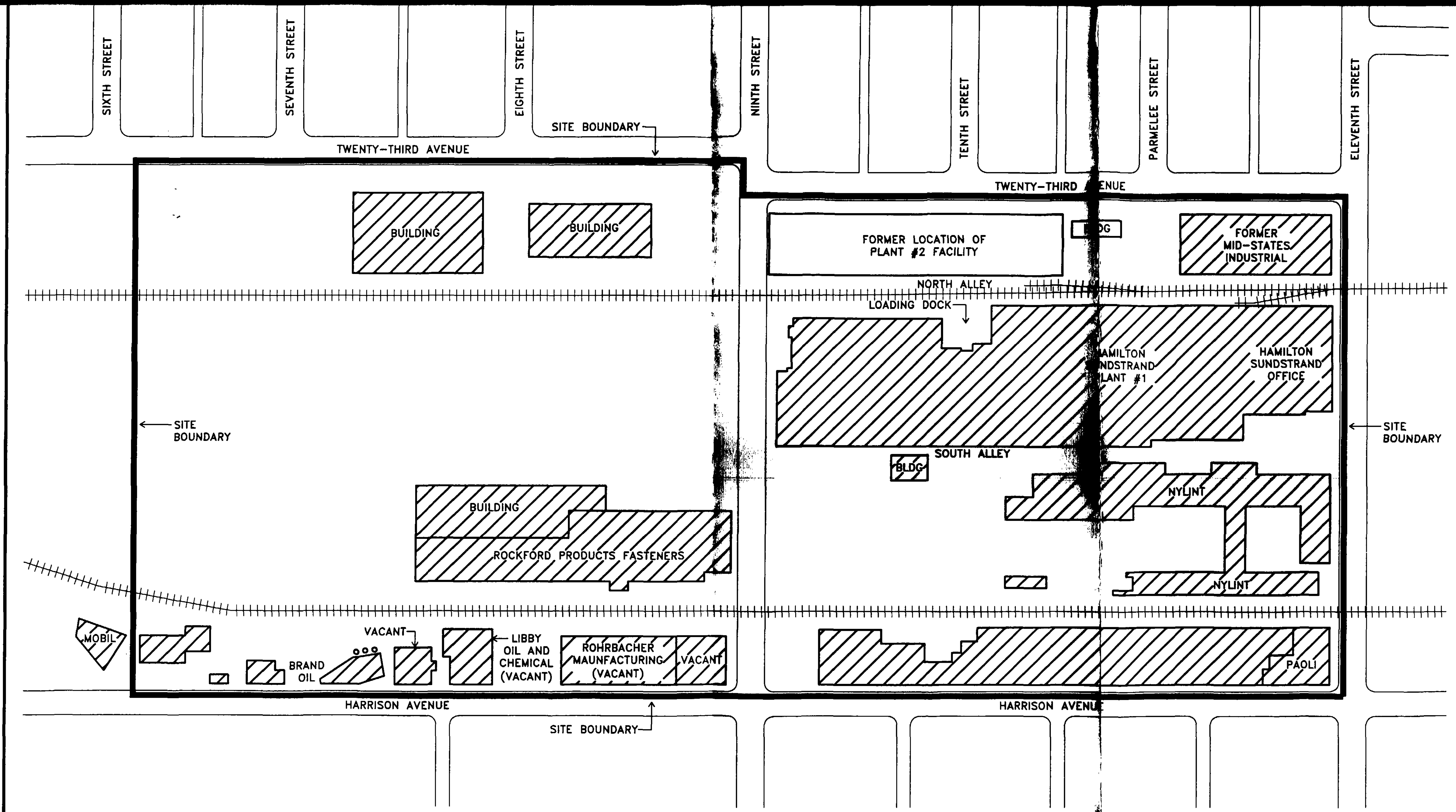

DESIGNED BY:	MGD
DRAWN BY:	GLH
APPROVED BY:	MGD
DATE:	6-17-03

SECOR

SITE MAP

HAMILTON SUNDSTRAND
AREA 9/10
ROCKFORD, ILLINOIS

JOB NO. 13UN.02072.00 FIGURE 2

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- Contaminant concentrations in extracted vapor; and
- Concentrations of carbon dioxide, oxygen, and methane in extracted vapor.

The objectives of the Pilot Test are to also obtain data on the following as it relates to air sparging (AS) design:

- Horizontal and vertical permeability;
- Breakthrough air pressure (injection pressure) required to force air into the saturated soil formation;
- Extent of water table mounding as a result of AS;
- Spatial geometry of air flow induced as a result of AS;
- Site conditions such as preferential air flow pathways or less permeable vadose zone layers that will influence vertical vapor migration;
- Air flow requirements;
- Contaminant concentrations in extracted vapor; and
- Concentrations of carbon dioxide, methane, and oxygen in extracted vapor.

In addition, the above data will be evaluated during simultaneous AS/SVE Pilot Testing operations.

PREVIOUS SVE PILOT TEST INFORMATION

Two SVE Pilot Tests were conducted by Harding Lawson Associates (HLA) at the Outside Container Storage Area (OSA) in June/July 1992. The first test was conducted by extracting vapor from native sandy soil between screened depths of 9 to 19 feet at the existing VEDM-5 location. A second test was conducted by extracting vapor from clayey sand fill between screened depths of 2.5 to 4.5 feet at the VESM-2 location.

Vapors were extracted from each extraction well with a positive displacement vacuum pump until the vapor flow rate fluctuated no more than 10 percent in a given hour. Induced vacuum was measured in six vadose zone monitoring wells using magnehelic vacuum gauges connected to the wellhead with air-tight fittings. Organic vapor concentrations in the vacuum pump exhaust were measured periodically with a photoionization detector (PID) equipped with a 10.2 eV lamp. Two samples of the vacuum pump exhaust were collected during each SVE test resulting in four total samples. A Tedlar® bag was connected to a fitting on the pump exhaust line using Tygon® tubing. The vapor sample in the Tedlar® bag was then pumped through Tenax® cartridges. The Tenax® cartridges were then chilled and shipped to an analytical laboratory for VOCs analysis using EPA Method TO1.

In the first SVE test (at VEDM-5 location), extraction well vacuum during the test ranged from 25.1 to 25.8 inches of water (in. H_2O) resulting in extraction vapor flow rates of 76 to 74 standard cubic feet per minute (scfm). In the second SVE test (at VESM-2 location), extraction well vacuum during the test ranged from 113 to 115 in. H_2O and extraction vapor flow rates ranged from 13 to 16 scfm.

Field PID readings reportedly ranged from 63 to 105 parts per million (ppmv). Perchloroethylene (PCE), Trichloroethylene (TCE), 1,1,1-trichloroethane (1,1,1-TCA) and xylenes were detected in the diluted vapor exhaust samples. Concentrations of the above compounds were higher during the second test, conducted in shallower, more contaminated soil.

In typical SVE system design, the radius of influence (ROI) is considered to be the distance at which vacuum is approximately 0.1 in. H_2O. Based on this assumption, the ROI in the deeper zone would be approximately 40 feet. In the shallow zone, the ROI would be 30 feet. Test results showed that induced vacuum was approximately 0.3% and 0.08% of the applied vacuum at these respective locations under HLA's Pilot Test conditions.

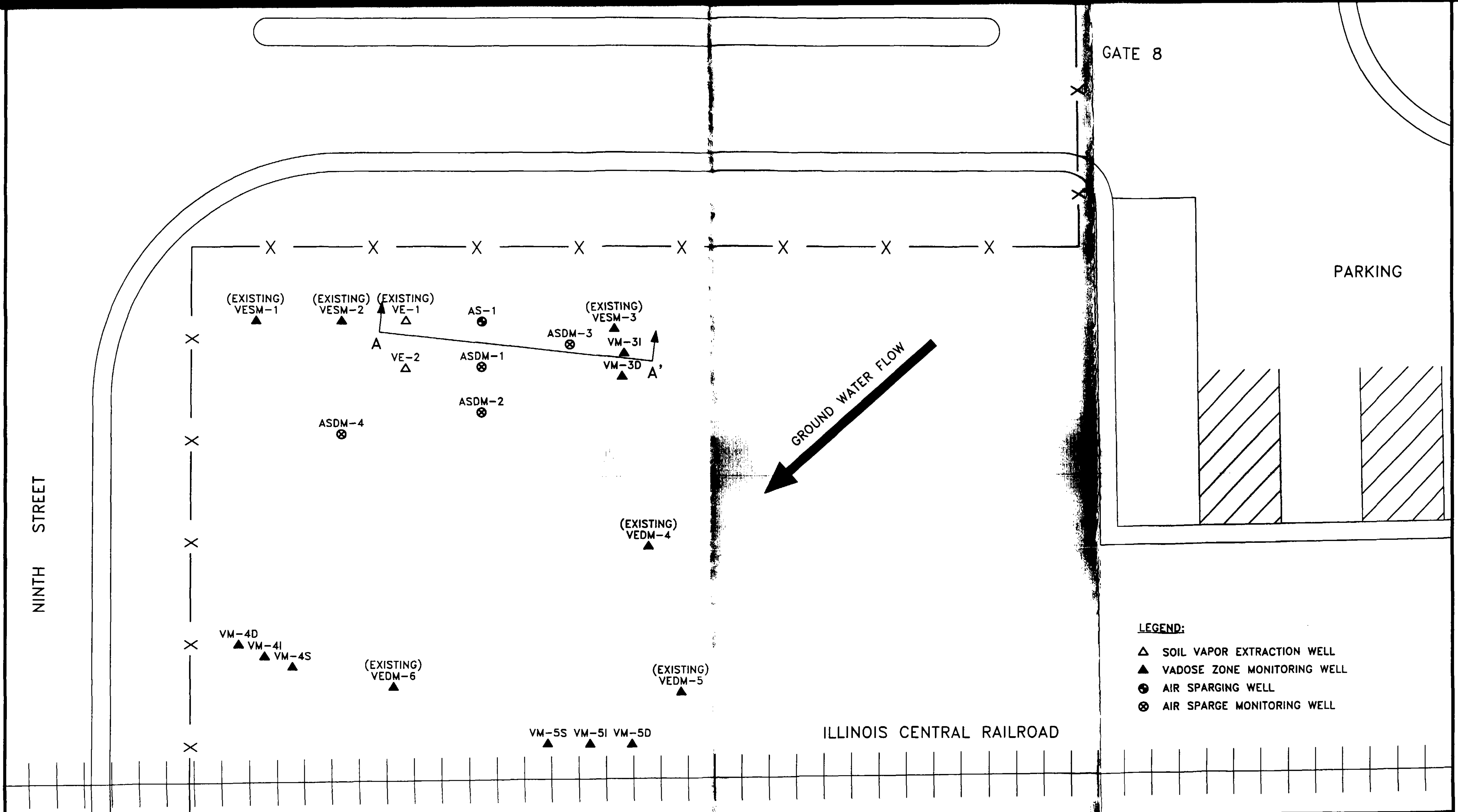
PILOT TEST WELL INSTALLATIONS

As described in the Field Sampling Plan, several existing wells located in the OSA are available for use during the Pilot Test. One additional SVE well, an AS well, four AS monitoring wells, two shallow vadose zone monitoring wells, three intermediate vadose zone monitoring wells and three deep vadose zone monitoring wells will be installed at the Site for the purpose of conducting the Pilot Test. Figure 3 depicts the locations of both existing and proposed wells for use during the Pilot Test. Figure 4 is a diagram of SVE well VE-1 (existing) to be used during Pilot Testing. Figure 5 is a diagram of proposed SVE well VE-2. Figure 6 illustrates construction details for shallow, intermediate, and deep vadose zone monitoring wells. Figure 7 is a diagram of proposed AS well, AS-1. A typical construction drawing for the four AS monitoring wells is show in Figure 8. Boring logs and well construction diagrams for existing wells installed by HLA in 1992 are located in Appendix A. Table 1.1 summarizes the rationale for the above well placements associated with the Pilot Test.

CONSTITUENTS OF CONCERN

Previous soil sampling at Area 9/10 had detected: methylene chloride (MCL) (possible laboratory artifact), 1,1,1-TCA, TCE, PCE, 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethene (1,2-DCE), acetone, and toluene. Previous groundwater sampling had detected: 1,1-DCE, 1,1-dichloroethane (1,1-DCA), 1,2-DCE, TCA, PCE, toluene, and xylene.

TABLE 1.1 Rationale for Well Placements Associated with the Pilot Test Remedial Design Area 9/10 Rockford, Illinois			
Well Number	**Boring depth/ Screen Interval Below Ground Surface**	**Location**	**Purpose**
ASDM 1 through 4	Screen interval approximately 25-40 feet	OSA	To enable collection of groundwater and sparged gas samples from both the vadose and saturated zone and depth to water table measurements during the Pilot Test. Groundwater samples for VOCs will also be collected.
VESM 1 through VESM 3 (Existing); VM-4S, VM-5S	Screen interval approximately 2.5-4.5 feet	OSA	To collect soil gas analytical, induced air flow and induced vacuum data from the upper part of the vadose zone to aid in the RD Pilot Test.
VM-3I through VM-5I	Screen interval approximately 15-17 feet	OSA	To collect soil gas analytical, induced air flow and induced vacuum data from the intermediate part of the vadose zone to aid in the RD Pilot Test.
VM-3D through VM-5D	Screen interval approximately 24-26 feet	OSA	To collect soil gas analytical, induced air flow and induced vacuum data from the deeper part of the vadose zone to aid in the RD Pilot Test
VEDM 4 through VEDM 6 (Existing)	Screen interval approximately 9-19 feet	OSA	To collect soil gas analytical information to aid in the design of the RD.
VE-1 (Existing)	Screen interval approximately 9-19 feet	OSA	To extract soil gas during the operation and evaluation of the RD Pilot Test.
VE-2	Screen interval approximately 22-27 feet	OSA	To extract soil gas during the operation and evaluation of the RD Pilot Test.
AS-1	Screen interval approximately 38-40 feet	OSA	To inject air beneath the water table during the operation and evaluation of the RD Pilot Test.
SMW-8	Screen interval approximately 25-40 feet	West side of the HS property, along the east side of 9th Street.	To collect groundwater monitoring data from the upper interval of the saturated zone in that area of the Site during the Pilot Test evaluation.



NOTE: CONCEPTUAL PURPOSES ONLY. LAYOUT FEATURES ARE BASED ON DRAWINGS PREPARED BY HARDING LAWSON ASSOCIATES, INC. 1992.

LEGEND:

- △ SOIL VAPOR EXTRACTION WELL
- ▲ VADOSE ZONE MONITORING WELL
- AIR SPARGING WELL
- ⊗ AIR SPARGE MONITORING WELL

DESIGNED BY:	LW
DRAWN BY:	GH
APPROVED BY:	
DATE:	6-12-03

SECOR

PILOT TEST SITE PLAN

HAMILTON SUNDSTRAND
AREA 9/10
ROCKFORD, ILLINOIS

JOB NO. 13UN.02072.00 FIGURE 3

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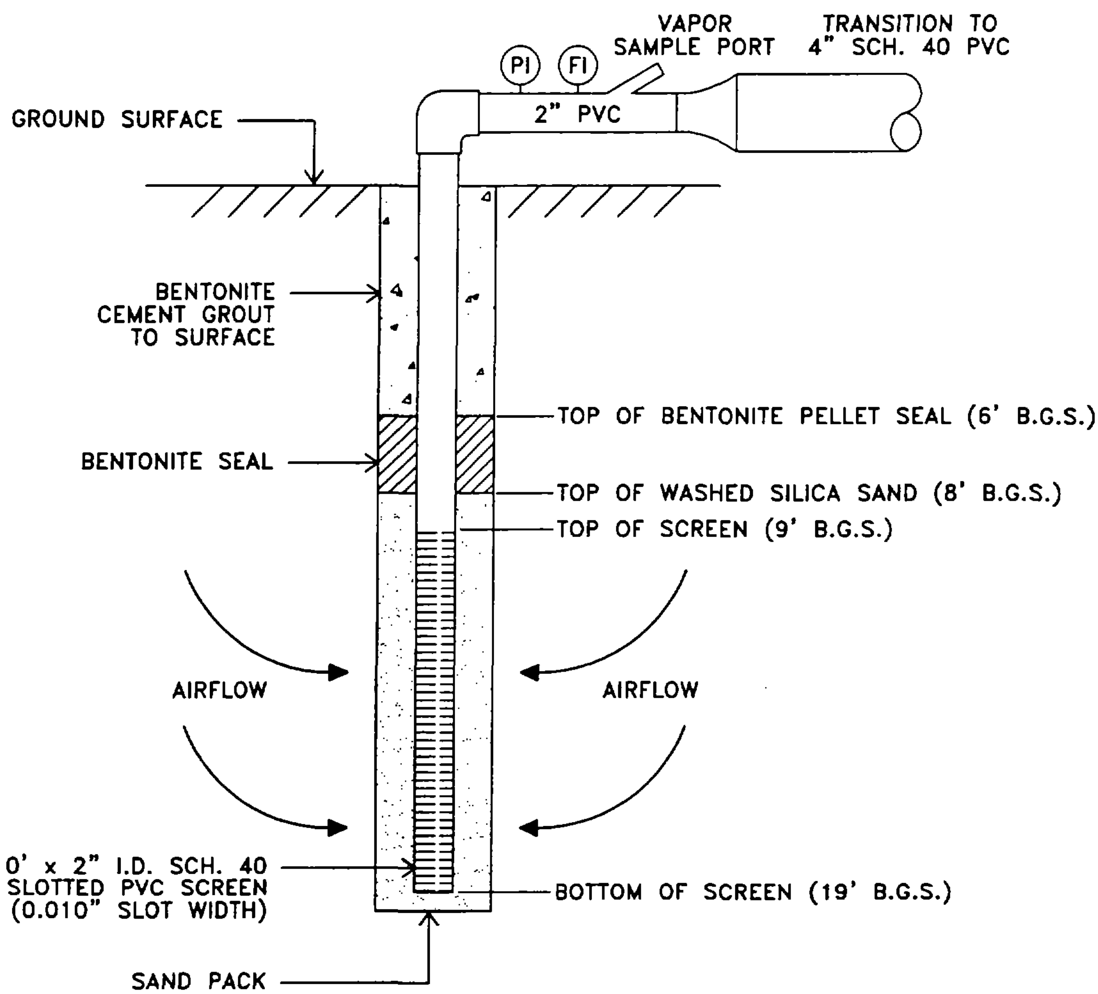

VERTICAL SCALE 1" = 5'-0"
NO HORIZONTAL SCALE

DESIGNED BY: LW	SECOR	VAPOR EXTRACTION WELL VE-1 (EXISTING) PILOT TEST HAMILTON SUNDSTRAND AREA 9/10 ROCKFORD, ILLINOIS
DRAWN BY: GH		
APPROVED BY:		
DATE: 6-11-03		JOB NO. 13UN.02072.00 FIGURE 4

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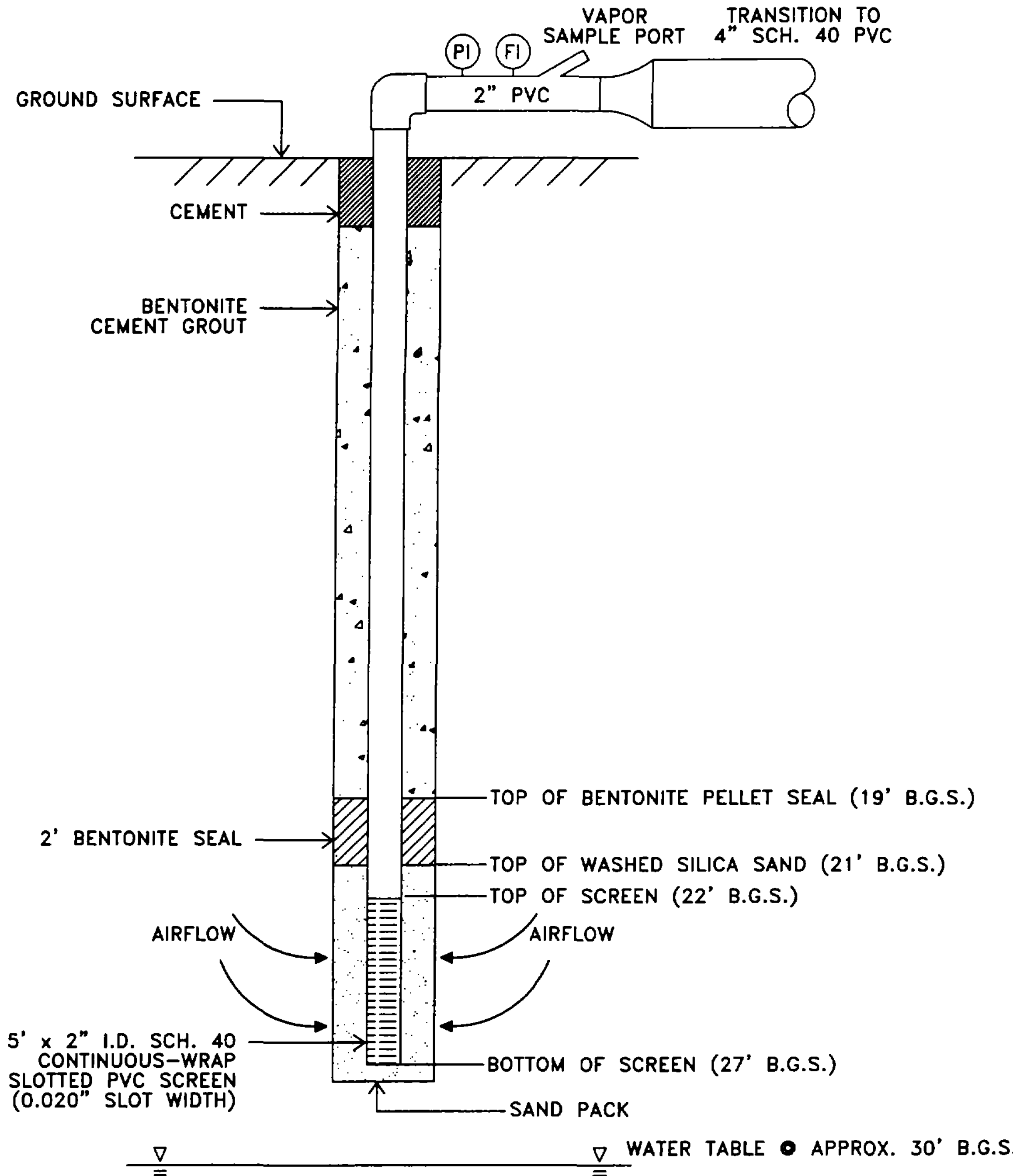

VERTICAL SCALE 1" = 5'-0"
NO HORIZONTAL SCALE

DESIGNED BY: LW	SECOR	VAPOR EXTRACTION WELL VE-2 PILOT TEST HAMILTON SUNDSTRAND AREA 9/10 ROCKFORD, ILLINOIS
DRAWN BY: GH		
APPROVED BY:		
DATE: 6-11-03		JOB NO. 13UN.02072.00 — FIGURE 5

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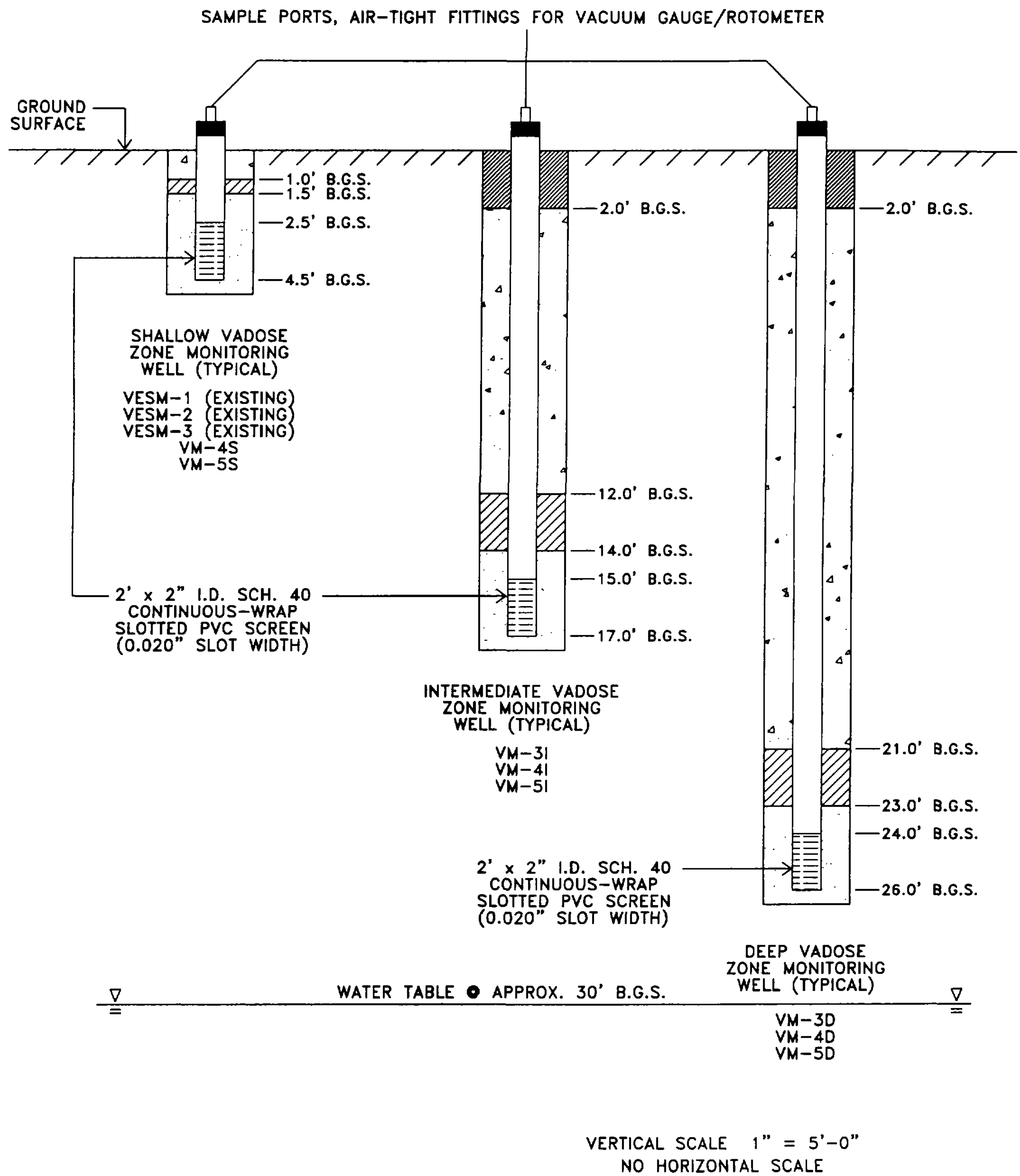

DESIGNED BY: LW	SECOR	VADOSE ZONE MONITORING WELLS (TYPICAL) PILOT TEST HAMILTON SUNDSTRAND AREA 9/10 ROCKFORD, ILLINOIS
DRAWN BY: GH		
APPROVED BY:		
DATE: 6-11-03		JOB NO. 13UN.02072.00 FIGURE 6

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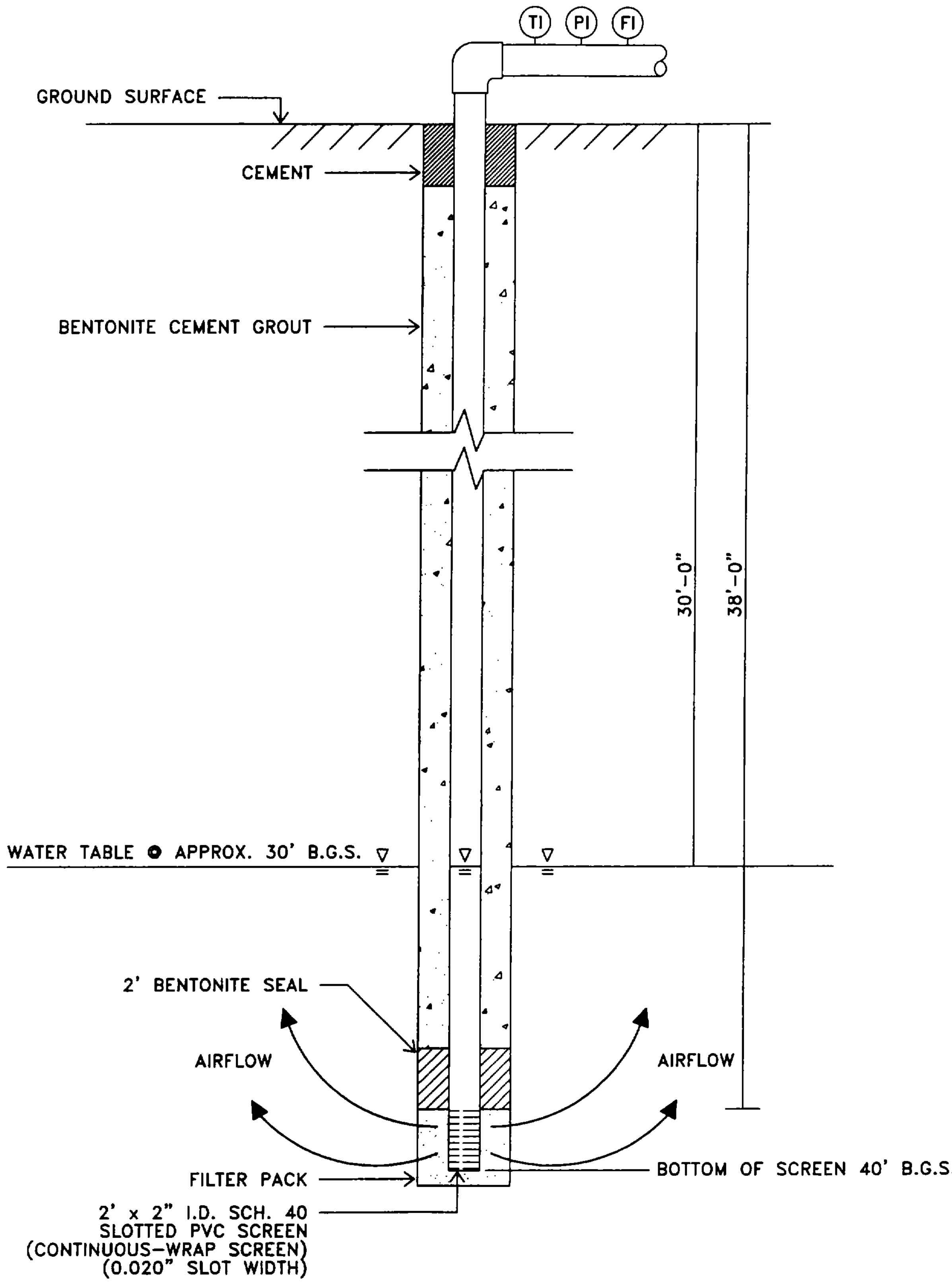

VERTICAL SCALE 1" = 5'-0"
NO HORIZONTAL SCALE

DESIGNED BY: LW	SECOR	AIR SPARGE WELL AS-1 PILOT TEST HAMILTON SUNDSTRAND AREA 9/10 ROCKFORD, ILLINOIS
DRAWN BY: GH		
APPROVED BY:		
DATE: 6-12-03		JOB NO. 13UN.02072.00 FIGURE 7

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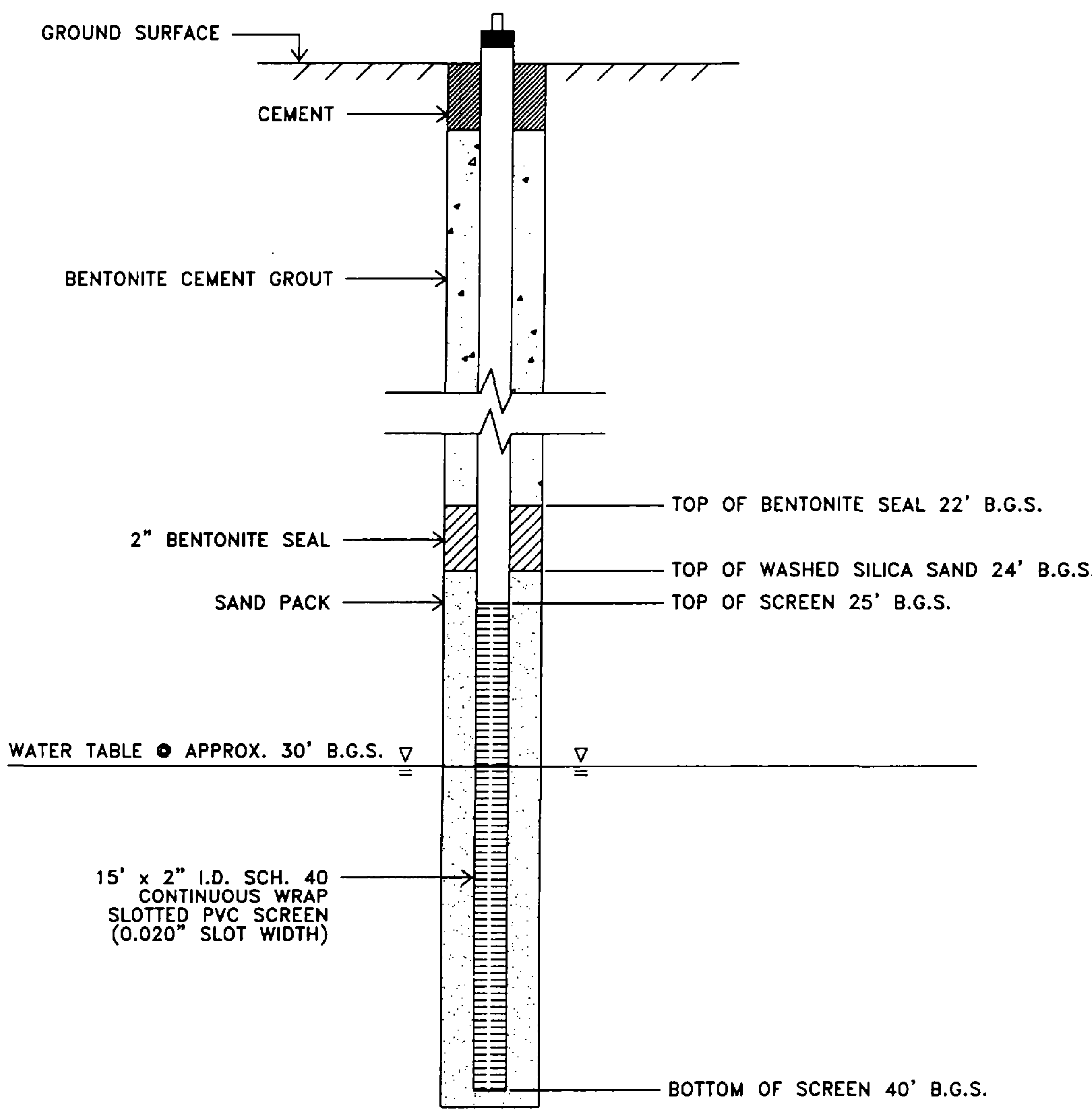


AIR SPARGE MONITORING WELL (TYPICAL)

VERTICAL SCALE 1" = 5'-0"
NO HORIZONTAL SCALE

DESIGNED BY: LW	SECOR	AIR SPARGE MONITORING WELL (TYPICAL) PILOT TEST HAMILTON SUNDSTRAND AREA 9/10 ROCKFORD, ILLINOIS
DRAWN BY: GH		
APPROVED BY:		
DATE: 6-12-03		JOB NO. 13UN.02072.00 FIGURE 8

SECTION 2.0
MOBILIZATION AND PILOT STUDY SETUP

AIR PERMIT REQUIREMENTS

A review of Illinois Air Regulations and correspondence with IEPA will be completed prior to Pilot Testing. If required, the substantive requirements of an Illinois Air Emissions (Minor Source) Operation Permit will be met. Off-gas treatment is not anticipated due to the expected short test duration and low mass of emissions.

UTILITY LOCATE

The presence of subsurface utility conduits (utilities) such as electrical, telephone, sewer, water lines, and process lines in the Pilot Test area can impact the effectiveness of the SVE system. Utilities can create preferential flow pathways, reducing the ROI. A joint meeting will be arranged with J.U.L.I.E. prior to conducting the Pilot Test to help determine the location of subsurface conduits in the area. In addition, plant maintenance personnel will be interviewed and facility plan drawings will be reviewed. Findings will be incorporated into a Site plan map.

SURFACE COVER

The nature of Site surface cover in the Pilot Test area can influence Pilot Test results. Impermeable surface cover such as concrete and asphalt can increase the ROI of an SVE system. Permeable surface cover materials allow more atmospheric air to enter the subsurface. If atmospheric air enters the subsurface in close proximity to the SVE well, short-circuiting occurs, reducing the ROI. Prior to completing Pilot Test activities, surface cover characteristics in the vicinity of the test area and their areal extent will be identified. Findings will be incorporated into a Site plan map.

SVE SYSTEM COMPONENTS

In general, the SVE system will consist of a regenerative blower, an air water separator, and an automatic transfer pump. The SVE system will be assembled as a skid-mounted system.

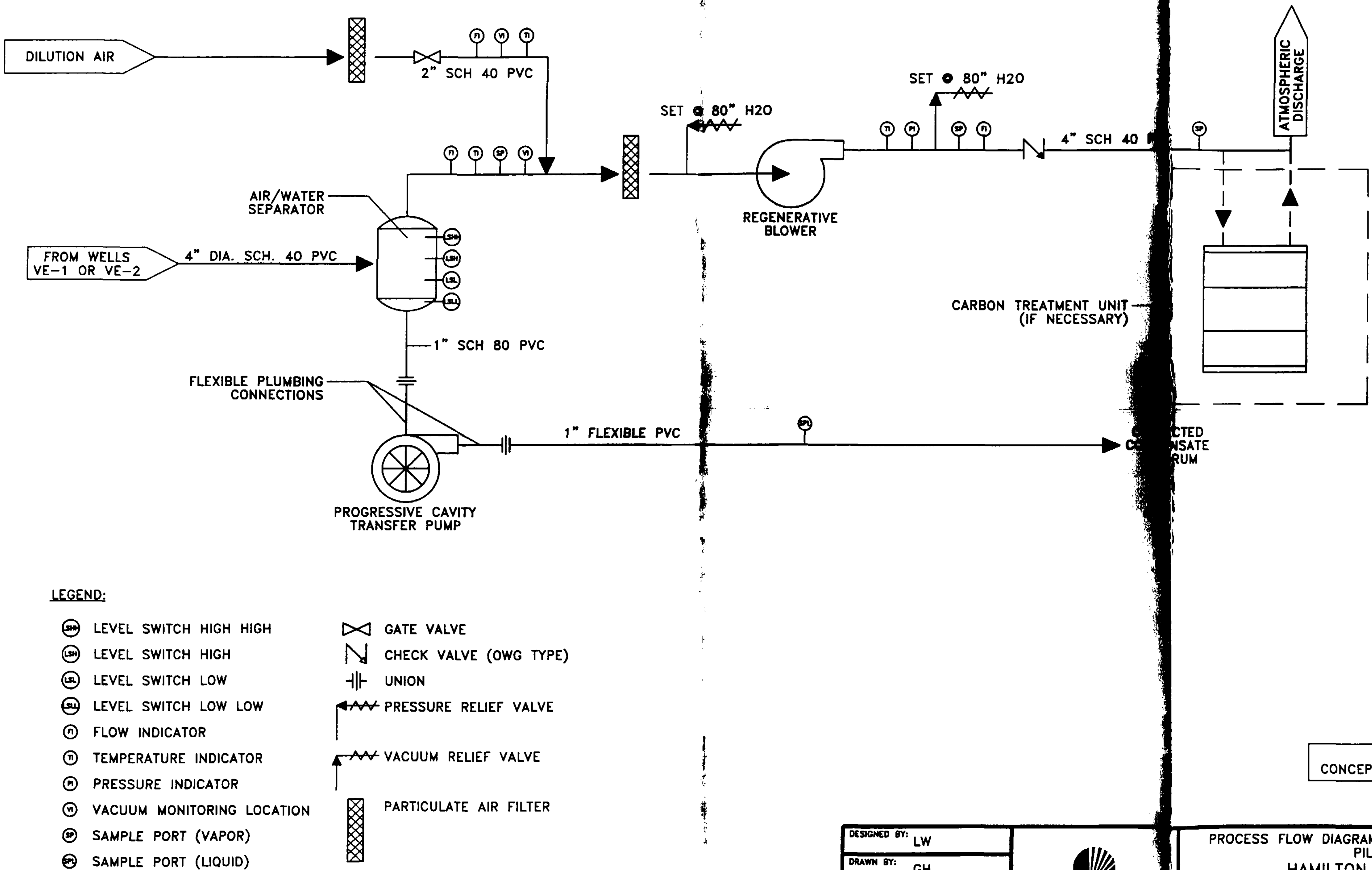
The regenerative blower shall be an Ametek® Rotron® EN6 or equivalent, having a maximum vacuum of 85 in. H_2O and a maximum flow rating of 225 scfm.

Immediately after extraction, soil gas is drawn into an air water separator or knockout vessel. The air water separator will be a Universal Silencer USS-4 or equivalent, equipped with an extra capacity sump. A transfer pump will be used to transfer accumulated liquid separated from the vapor stream to a 55-gallon drum. The separator will have four level switches. Level Switch High (LSH) will signal the transfer pump to begin pumping accumulated condensate water from the separator to a collection drum. Level Switch High High (LSHH) will signal the blower to shut down while the transfer pump empties the separator sump. Level Switch Low (LSL) will signal the blower to start. Level Switch Low Low (LSLL) will signal the transfer pump to shut off.

Figure 9 is a Process Flow Diagram of the proposed SVE system. Copies of specifications data for the regenerative blower are provided in Appendix B.

AIR SPARGE (AS) SYSTEM

The AS system will consist of an air compressor equipped with a coalescing oil removal filter rated at 0.01 microns and a compressed helium supply. The compressed air and helium lines will have a pressure regulator, throttle valve, pressure indicator, flow rate indicator, and temperature indicator. Downstream of the union between the compressed air and helium lines, a temperature indicator, pressure indicator, and flow rate indicator will be located before the sparge wellhead assembly.



NOT TO SCALE
CONCEPTUAL PURPOSES ONLY

DESIGNED BY: LW	SECOR	PROCESS FLOW DIAGRAM OF PROPOSED SVE SYSTEM PILOT TEST HAMILTON SUNDSTRAND AREA 9/10 ROCKFORD, ILLINOIS	
DRAWN BY: GH			
APPROVED BY:			
DATE: 6-16-03		JOB NO. 13UN.02072.00	FIGURE 9

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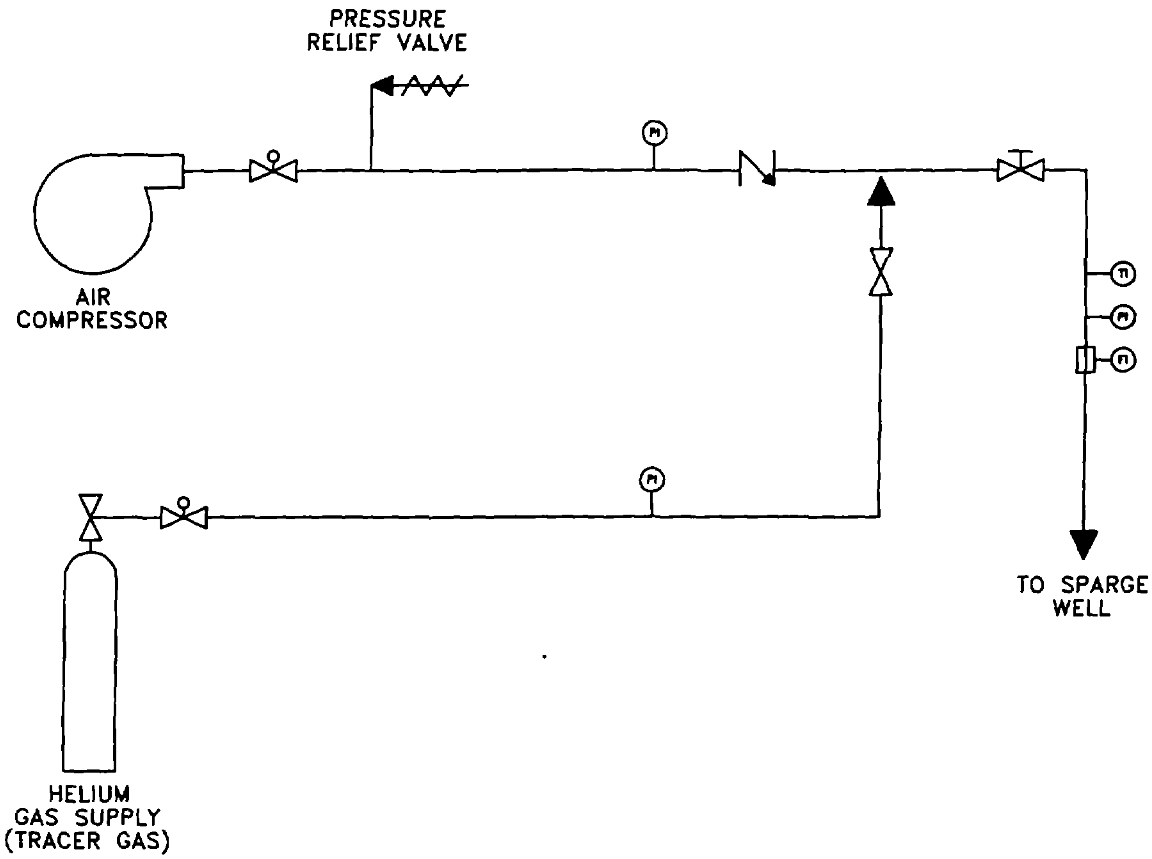
Figure 10 is a Process Flow Diagram of the proposed AS system. Figure 11 is a conceptual profile of the SVE wells, AS well, vadose zone monitoring wells, and saturated zone well locations.

COORDINATION OF ELECTRIC SERVICE

Prior to SVE and AS systems setup on-site, overhead service drop, weather head, and meter box connection will be coordinated with the local electric utility. If deemed appropriate, electrical service may be provided by a portable generator. The portable generator will meet the power requirements of the AS/SVE equipment. The regenerative blower on the SVE system is equipped with a dual voltage 3-phase motor certified to operate with either 208-230/415-460 voltage AC – 60 Hz. The blower motor can handle a ± 10% voltage fluctuation. The transfer pump on the SVE system is equipped with a single phase, 230-voltage AC – 60 Hz motor

WELLHEAD CONNECTION

The SVE system and the AS system will be connected to their respective wellheads prior to commencement of the Pilot Test. Air-tight fittings will be used. A vacuum indicator, flow rate indicator, temperature indicator, and sample port will be installed between the wellhead and the SVE system air-water separator to allow for monitoring of raw extraction vapors.



LEGEND:

- FLOW INDICATOR
- TEMPERATURE INDICATOR
- PRESSURE INDICATOR
- GATE VALVE
- THROTTLE VALVE
- PRESSURE REGULATOR
- CHECK VALVE (OWG TYPE)

NOTES:

1. AIR COMPRESSOR TO BE EQUIPPED WITH A COALESCING OIL REMOVAL FILTER RATED AT 0.01 MICRONS.

NOT TO SCALE
CONCEPTUAL PURPOSES ONLY

DESIGNED BY: LW	SECOR	PROCESS FLOW DIAGRAM OF PROPOSED AS SYSTEM PILOT TEST HAMILTON SUNDSTRAND AREA 9/10 ROCKFORD, ILLINOIS
DRAWN BY: GH		
APPROVED BY:		
DATE: 6-16-03		JOB NO. 13UN.02072.00 FIGURE 10

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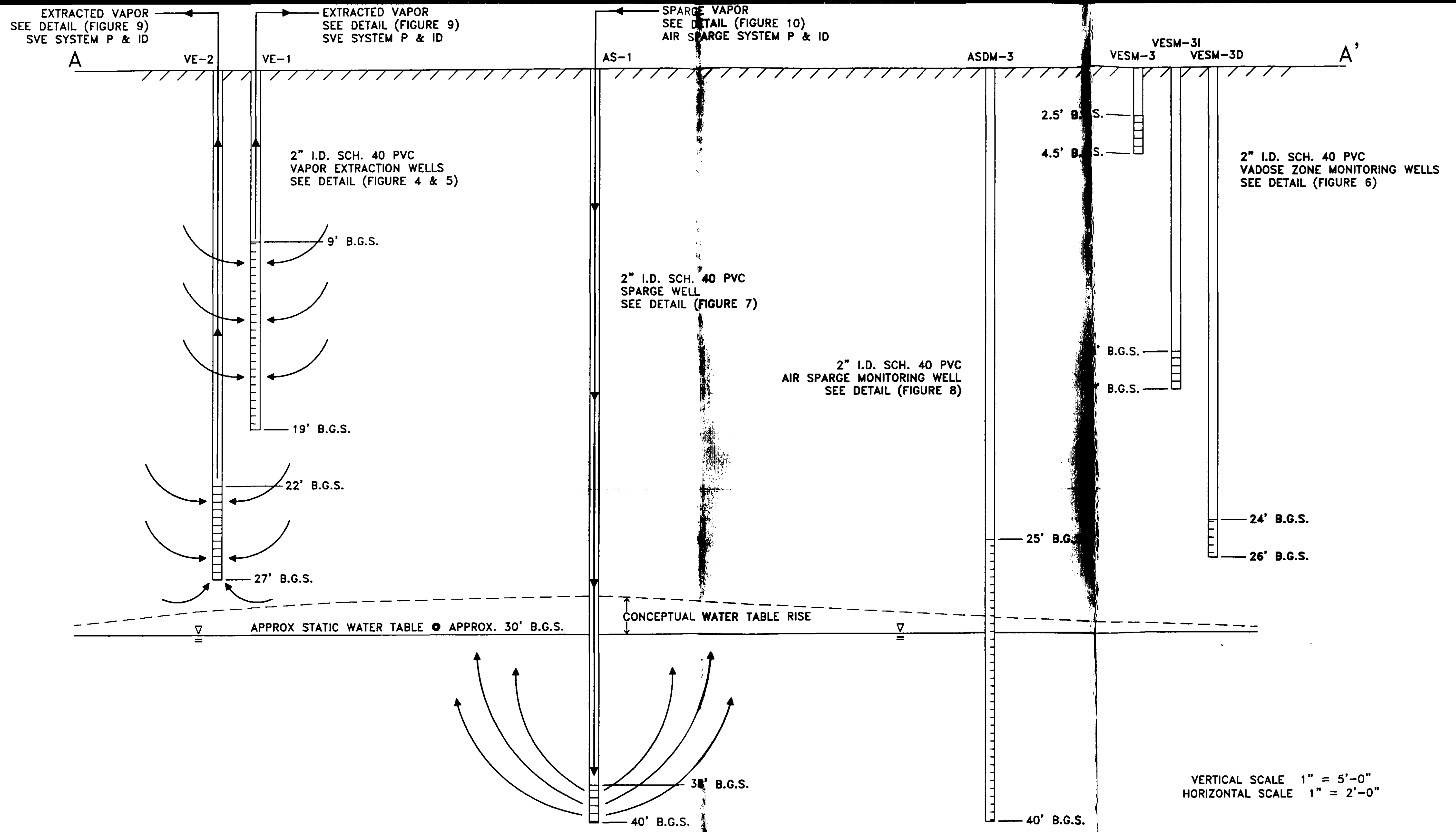

DESIGNED BY:	LW
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APPROVED BY:	
DATE:	6-16-03

SECOR

CONCEPTUAL PROFILE A – A'
PILOT TEST
HAMILTON SUNDSTRAND
AREA 9/10
ROCKFORD, ILLINOIS

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FIGURE 11

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SECTION 3.0
PILOT TEST METHODS AND PROCEDURES

Pilot Testing will consist of four components described as follows: SVE Step Tests at extraction wells VE-1 and VE-2, Constant Rate SVE Tests at extraction wells VE-1 and VE-2, an AS test, and Combined AS/SVE tests.

SVE STEP TEST

The purpose of the SVE Step Test is to evaluate extraction well vapor flow characteristics and observe the relationship between applied vacuum and induced vapor flow rate. An optimum vacuum for the Site will be selected based on a graph of the data. The goal is to identify the point at which increased vacuum provides only a modest increase in airflow. The optimum vacuum estimate is crucial to SVE system design. Over-sizing of the system will result in additional capital and operating costs.

The SVE Step Test will be conducted as follows:

1. Measure depth to water in each monitoring well screened in the saturated zone;
2. Measure carbon dioxide concentration, methane concentration, and percent oxygen in extraction well using a portable multi-gas detector;
3. Measure organic vapor concentration in extraction well using a PID and/or flame ionization detector (FID);
4. Open dilution air inlet valve;
5. Close inlet valve at wellhead;
6. Turn on vacuum blower and record the following information:
    a. Date;
    b. Time;
    c. Flow rate from extraction well;
    d. Vacuum at extraction well;

e. Flow rate from blower discharge stack (should be equal to maximum blower flow rating when dilution air inlet valve is completely open);
f. Oxygen, carbon dioxide, and methane concentrations in extracted vapor using a portable multi-gas detector;
g. Organic vapor concentrations measured with a PID and/or FID;
h. Vacuum in each vadose zone monitoring well;
i. Flow rate in each vadose zone monitoring well;
j. Depth to water in monitoring wells screened across the water table.
k. Ambient barometric pressure;
l. Ambient temperature;
m. Volume of condensate/sediment generated and pumped out of the air water separator; and
n. If desired, collect an extraction vapor sample for laboratory analysis of VOCs.

7. Open valve at wellhead;
8. Record data from 6a through 6n;
9. Slowly and partially close the dilution air inlet valve. The goal is to incrementally increase vacuum at the extraction well, allow flow rate and vacuum to stabilize (+/- 10%), and then record the data listed in 6a through 6n;
10. Continue the "stepped" process of increasing vacuum and recording data until the dilution air inlet valve is fully closed;
11. Reverse the process in nearly the same increments by decreasing the vacuum on the extraction well (by opening the dilution air inlet valve in steps). Repeat the monitoring for each step; and
12. After the last step is complete and the dilution air valve is completely open, close the valve at the extraction wellhead and shut down the vacuum blower.

At least six to ten "steps" are desired. For example, testing at 5, 10, 20, 30, 40, 50, 60, 70, 80, and 85 in. H_2O would be acceptable.

Following completion of the above step test, a graph of applied vacuum (in. H_2O) versus vapor flow rate in actual cubic feet per minute (acfm) will be plotted. Using the plot, an optimum vacuum for the Site will be selected.

At least two vapor samples will be collected during each step test and submitted to the laboratory for analysis of VOCs.

The above procedure will be completed twice, first at extraction well VE-1 *and again at* VE-2.

CONSTANT RATE SVE TEST

The purpose of the Constant Rate SVE Test is to evaluate the induced air flow rates and vacuum within the network of vadose zone monitoring wells surrounding the extraction well. The Constant Rate SVE Test will be conducted at the optimum vacuum for the Site estimated as a result of the Step Test. The goal of the Constant Rate SVE Test is to determine the ROI of the extraction well based on detected air flow rates within observation wells. The ROI estimate will be used to design the number and location of extraction wells necessary to cover any contaminated plume areas identified during planned pre-design investigative activities presented in the Remedial Design Work Plan dated February 27, 2003, as amended and approved by USEPA.

The Constant Rate SVE Test will be conducted as follows:

1. Measure depth to water in each monitoring well screened in the saturated zone;
2. Measure carbon dioxide concentration, methane concentration, and percent oxygen in extraction well using a portable multi-gas detector;
3. Measure organic vapor concentration in extraction well using a PID and/or FID;
4. Open dilution air inlet valve;

SVE may also be appropriate near a building foundation to prevent vapor migration into the building. Here, the primary goal may be to control vapor migration and not necessarily to remediate soil.

Pilot Scale Studies

At this stage, you will be in a position to decide if SVE is likely to be highly effective, somewhat effective, or ineffective. If it appears that SVE will be only marginally to moderately effective at a particular site, make sure that SVE pilot studies have been completed at the site and that they demonstrate SVE effectiveness. Pilot studies are an extremely important part of the design phase. Data provided by pilot studies is necessary to properly design the full-scale SVE system. Pilot studies also provide information on the concentration of volatile organic compounds (VOCs) that are likely to be extracted during the early stages of operation of the SVE system.

While pilot studies are important and recommended for evaluating SVE effectiveness and design parameters for any site, they are particularly useful at sites where SVE is expected to be only marginally to moderately effective. Pilot studies typically include short-term (1 to 30 days) extraction of soil vapors from a single extraction well, which may be an existing monitoring well at the site. However, longer pilot studies (up to 6 months) which utilize more than one extraction well may be appropriate for larger sites. Different extraction rates and wellhead vacuums are applied to the extraction wells to determine the optimal operating conditions. The vacuum influence at increasing distances from the vapor extraction well is measured using vapor probes or existing wells to establish the pressure field induced in the subsurface by operation of the vapor extraction system. The pressure field measurements can be used to define the design radius of influence for SVE. Vapor concentrations are also measured at two or more intervals during the pilot study to estimate initial vapor concentrations of a full-scale system. The vapor concentration, vapor extraction rate and vacuum data are also used in the design process to select extraction and treatment equipment.

Section 7-1 suggest

In some instances, it may be appropriate to evaluate the potential of SVE effectiveness using a screening model such as HyperVentilate (EPA, 1993). HyperVentilate can be used to identify required site date, decide if SVE is appropriate at a site, evaluate air permeability tests, and estimate the minimum number of wells needed. It is not intended to be a detailed SVE predictive modeling or design tool.

from "How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers: Chapter II: Soil Vapor Extraction"

URL: http://www.epa.gov/swerust1/pubs/tum_ch2.pdf

Evaluation Of The SVE System Design

Once you have verified that SVE is applicable, you can scrutinize the design of the system. A pilot study that provides data used to design the full-scale SVE system is highly recommended. The CAP should include a discussion of the rationale for the design and presentation of the conceptual engineering design. Detailed engineering design documents might also be included, depending on state requirements. Further detail about information to look for in the discussion of the design is provided below.

Rationale For The Design

Consider the following factors as you evaluate the design of the SVE system in the CAP.

- *Design Radius of Influence (ROI)* is the most important parameter to be considered in the design of an SVE system. The ROI is defined as the greatest distance from an extraction well at which a sufficient vacuum and vapor flow can be induced to adequately enhance volatilization and extraction of the contaminants in the soil. As a rule-of-thumb, the ROI is often considered to be the distance from the extraction well at which a vacuum of at least 0.1 inches of water is observed.

  The ROI depends on many factors including: lateral and vertical permeability; depth to the groundwater table; the presence or absence of a surface seal; the use of injection wells; and the extent of soil heterogeneity. Generally, the design ROI can range from 5 feet (for fine grained soils) to 100 feet (for coarse grained soils). For sites with stratified geology, design ROI should be defined for each soil type. The ROI is important for determining the appropriate number and spacing of extraction wells. The ROI should be determined based on the results of pilot study testing; however, at sites where pilot tests can not be performed, the ROI can be estimated using air flow modelling or other empirical methods.

- *Wellhead Vacuum* is the vacuum pressure that is required at the top of the extraction well to produce the desired vapor extraction flow rate from the extraction well. Although wellhead vacuum is usually determined through pilot studies, it can be estimated and typically ranges from 3 to 100 inches of water vacuum. Less permeable soils generally require higher wellhead vacuum pressures to produce a reasonable radius of influence. It should be noted, however, that high vacuum pressures (e.g., greater than 100 inches of water) can cause upwelling of the water table and occlusion of the extraction well screens.

- *Vapor Extraction Flow Rate* is the volumetric flow rate of soil vapor that will be extracted from each vapor extraction well. Vapor extraction flow rate, radius of influence, and wellhead vacuum are interdependent (e.g., a change in the extraction rate will cause a change in the wellhead vacuum and radius of influence). Vapor extraction flow rate should be determined from pilot studies but may be calculated using mathematical or physical models (EPA 1993). The flow rate will contribute to the operational time requirements of the SVE system. Typical extraction rates can range from 10 to 100 cubic feet per minute (cfm) per well.

- *Initial Constituent Vapor Concentrations* can be measured during pilot studies or estimated from soil gas samples or soil samples. They are used to estimate constituent mass removal rate and SVE operational time requirements and to determine whether treatment of extracted vapors will be required prior to atmospheric discharge or reinjection.

  The initial vapor concentration is typically orders of magnitude higher than the sustained vapor extraction concentration and can be expected to last only a few hours to a day before dropping off significantly. Vapor treatment is especially important during this early phase of remediation.

- *Required Final Constituent Concentrations* in soils or vapors are either defined by state regulations as "remedial action levels," or determined on a site-specific basis using fate and transport modeling and risk assessment. They will determine what areas of the site require treatment and when SVE operation can be terminated.

- *Required Remedial Cleanup Time* may also influence the design of the system. The designer may reduce the spacing of the extraction wells to increase the rate of remediation to meet cleanup deadlines or client preferences, as required.

- *Soil Volume To Be Treated* is determined by state action levels or a site-specific risk assessment using site characterization data for the soils.

- *Pore Volume Calculations* are used along with extraction flow rate to determine the pore volume exchange rate. The exchange rate is calculated by dividing the soil pore space within the treatment zone by the design vapor extraction rate. The pore space within the treatment zone is calculated by multiplying the soil porosity by the volume of soil to be treated. Some literature suggests that one pore volume of soil vapor should be extracted at least daily for effective remedial progress.

You can calculate the time required to exchange one pore volume of soil vapor using the following equation:

$$E = \frac{(m^3 \text{ vapor } / \text{ } m^3 \text{ soil}) \cdot (m^3 \text{ soil})}{(m^3 \text{ vapor } / \text{ hr})} = \text{hr}$$

where: E = pore volume exchange time (hr)
ε = soil porosity (m^3 vapor/m^3 soil)
V = volume of soil to be treated (m^3 soil)
Q = total vapor extraction flowrate (m^3 vapor/hr)

$$E = \frac{\varepsilon V}{Q}$$

- *Discharge Limitations And Monitoring Requirements* are usually established by state regulations but must be considered by designers of an SVE system to ensure that monitoring ports are included in the system hardware. Discharge limitations imposed by state air quality regulations will determine whether offgas treatment is required.
- *Site Construction Limitations* such as building locations, utilities, buried objects, residences, and the like must be identified and considered in the design process.

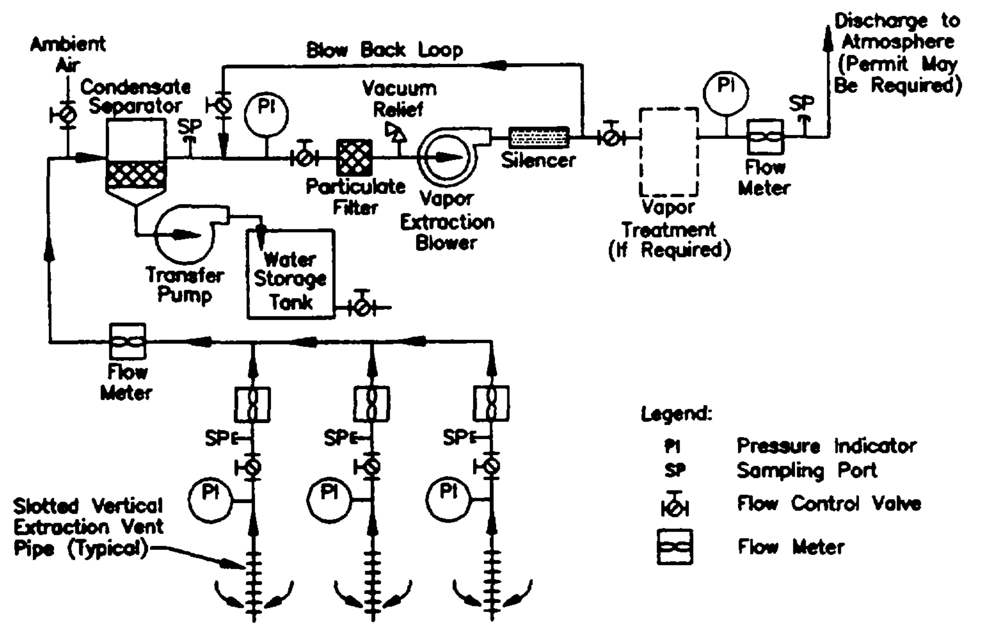
Components Of An SVE System

Once the rationale for the design is defined, the actual design of the SVE system can be developed. A typical SVE system design will include the following components and information:

- Extraction wells
- Well orientation, placement, and construction details
- Manifold piping
- Vapor pretreatment design
- Blower selection
- Instrumentation and control design
- Optional SVE components
  - Injection wells
  - Surface seals
  - Groundwater depression pumps
  - Vapor treatment systems

Exhibit II-11 is a schematic diagram of an SVE system.

Exhibit II-11
Schematic Of A Soil Vapor Extraction System



The following subsections provide guidance for reviewing the system configuration, standard system components, and additional system components.

Extraction Wells

Well Orientation. An SVE system can use either vertical or horizontal extraction wells. Orientation of the wells should be based on site-specific needs and conditions. Exhibit II-12 lists site conditions and the corresponding appropriate well orientation.

Well Placement And Number Of Wells. Determine the number and location of extraction wells by using several methods. In the first method, you divide the area of the site requiring treatment by the area of influence for a single well to obtain the total number of wells needed. Then, space the wells evenly within the treatment area to provide areal coverage so that the areas of influence cover the entire area of contamination.

$$\text{Area of influence for a single well} = \pi \cdot (\text{ROI})^2$$

$$\text{Number of wells needed} = \frac{\text{Treatment area (m}^2)}{\text{Area of influence for single extraction well (m}^2/\text{well)}}$$

Exhibit II-12
Well Orientation And Site Conditions

Well Orientation	Site Conditions
Vertical extraction well	○ Shallow to deep contamination (5 to 100+ feet). ○ Depth to groundwater > 10 feet.
Horizontal extraction well	○ Shallow contamination (< 25 feet). More effective than vertical wells at depths < 10 feet. Construction difficult at depths > 25 feet. ○ Zone of contamination confined to a specific stratigraphic unit.

In the second method, determine the total extraction flow rate needed to exchange the soil pore volume within the treatment area in a reasonable amount of time (8 to 24 hours). Determine the number of wells required by dividing the total extraction flow rate needed by the flow rate achievable with a single well.

$$\text{Number of wells needed} = \frac{\varepsilon V / t}{q}$$

where:
ε = soil porosity (m^3 vapor / m^3 soil)
V = volume of soil in treatment area (m^3 soil)
q = vapor extraction rate from single extraction well (m^3 vapor/hr).
t = pore volume exchange time (hours)

In the example below, an 8-hour exchange time is used.

$$\text{Number of wells needed} = \frac{\left(\frac{m^3\ \text{vapor}}{m^3\ \text{soil}}\right) \cdot \left(\frac{(m^3\ \text{soil})}{8\ \text{hrs}}\right)}{\frac{m^3\ \text{vapor}}{\text{hr}}}$$

Consider the following additional factors in determining well spacing.

○ Use closer well spacing in areas of high contaminant concentrations to increase mass removal rates.

- If a surface seal exists or is planned for the design, space the wells slightly farther apart because air is drawn from a greater lateral distance and not directly from the surface. However, be aware that this increases the need for air injection wells.

- At sites with stratified soils, wells that are screened in strata with low intrinsic permeabilities should be spaced more closely than wells that are screened in strata with higher intrinsic permeabilities.

Well Construction. *Vertical Well Construction.* Vertical extraction wells are similar in construction to groundwater monitoring wells and are installed using the same techniques. Extraction wells are usually constructed of polyvinyl chloride (PVC) casing and screening. Extraction well diameters typically range from 2 to 12 inches, depending on flow rates and depth; a 4-inch diameter is most common. In general, 4-inch-diameter wells are favored over 2-inch-diameter wells because 4-inch-diameter wells are capable of higher extraction flow rates and generate less frictional loss of vacuum pressure.

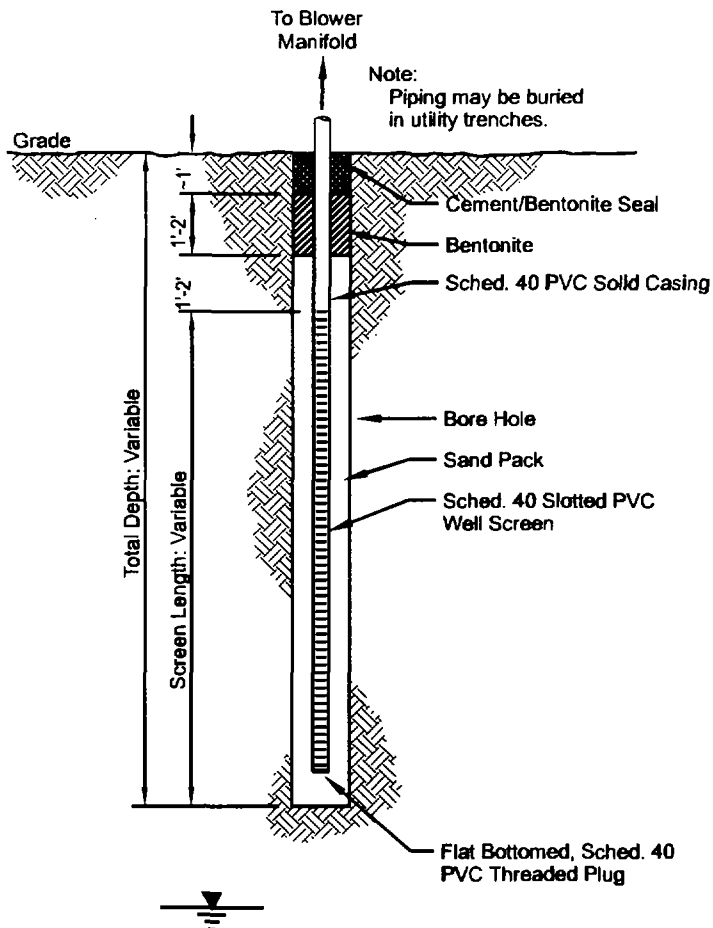
Exhibit II-13 depicts a typical vertical extraction well. Vertical extraction wells are constructed by placing the casing and screen in the center of a borehole. Filter pack material is placed in the annular space between the casing/screen and the walls of the borehole. The filter pack material extends 1 to 2 feet above the top of the well screen and is followed by a 1- to 2-foot-thick bentonite seal. Cement-bentonite grout seals the remaining space up to the surface. Filter pack material and screen slot size must be consistent with the grain size of the surrounding soils.

The location and length of the well screen in vertical extraction wells can vary and should be based on the depth to groundwater, the stratification of the soil, and the location and distribution of contaminants. In general, the length of the screen has little effect on the ROI of an extraction well. However, because the ROI is affected by the intrinsic permeability of the soils in the screened interval (lower intrinsic permeability will result in a smaller ROI, other parameters being equal), the placement of the screen can affect the ROI.

- At a site with homogeneous soil conditions, ensure that the well is screened throughout the contaminated zone. The well screen may be placed as deep as the seasonal low water table. A deeper well helps to ensure remediation of the greatest amount of soil during seasonal low groundwater conditions.

- At a site with stratified soils or lithology, check to see that the screened interval is within the zone of lower permeability because preferred flow will occur in the zones of higher permeability.

Exhibit II-13
Typical Vertical Soil Vapor Extraction Well Construction



Horizontal Well Construction. Look for horizontal extraction wells or trench systems in shallow groundwater conditions. Exhibit II-14 shows a typical shallow horizontal well construction detail. Horizontal extraction wells are constructed by placing slotted (PVC) piping near the bottom of an excavated trench. Gravel backfill surrounds the piping. A bentonite seal or impermeable liner is added to prevent air leakage from the surface. When horizontal wells are used, the screen must be high enough above the groundwater table that normal groundwater table fluctuations do not submerge the screen. Additionally, vacuum pressures should be monitored such that they do not cause upwelling of the groundwater table that could occlude the well screen(s).

You should verify that laboratory measurements of total dissolved iron have been completed for groundwater samples from the site. Use Exhibit VII-12 to determine the range where dissolved iron is a concern for air sparging effectiveness.

Exhibit VII-12
Dissolved Iron And Air Sparging Effectiveness

Dissolved Iron Concentration (mg/L)	Air Sparging Effectiveness
$Fe^{+2} < 10$	Air sparging effective
$10 \leq Fe^{+2} \leq 20$	Air sparging wells require periodic testing and may need periodic replacement
$Fe^{+2} > 20$	Air sparging not recommended

Field Pilot-Scale Studies

Field pilot studies are necessary to adequately design and evaluate any air sparging system. However, pilot tests should not be conducted if free product is known to exist at the groundwater table, if uncontrolled vapors could migrate into confined spaces, sewers, or buildings, or if the contaminated groundwater is in an unconfined aquifer. The air sparge well used for pilot testing is generally located in an area of moderate constituent concentrations. Testing the system in areas of extremely low constituent concentrations may not provide sufficient data. In addition, because sparging can induce migration of constituents, pilot tests are generally not conducted in areas of extremely high constituent concentrations. The air sparging pilot study should include an SVE pilot study if SVE is to be included in the design of the air sparging system.

Pilot studies for air sparging often include SVE pilot testing to determine if SVE can be used to effectively control the vapor plume. Pilot studies, therefore, should include the installation of a single sparge point, several vapor extraction points (if SVE is to be included in the design), and soil gas monitoring points to evaluate vapor generation rates and to define the vapor plume. Existing groundwater monitoring wells (normally not fewer than three to five wells around the plume) that have been screened above the saturated zone and through the dissolved phase plume can be used to monitor both dissolved and vapor phase migration, to monitor for changes in dissolved oxygen, and to measure changes in the depth to the groundwater table surface. Additional vapor probes should be used to further define the vapor plume and identify any preferential migration pathways. These probes should be designed and installed as discussed in Chapter II: Soil Vapor Extraction.

(p. 3-5 suggests 5 GW wells be checked

from "How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers" Chapter VII: Air Sparging

URL http://www.epa.gov/swerust1/pubs/tum_ch7.pdf

If SVE is to be used in the air sparging system, the first portion of the test should be conducted using vapor extraction only and evaluated as described in Chapter II: Soil Vapor Extraction without the air sparging system being operated. This portion of the pilot test will establish the baseline vapor extraction levels, the extent of the non-sparged vapor plume, the SVE well radius of influence, and the intrinsic permeability of the unsaturated zone (discussed in Chapter II). The air sparging portion of the test should be conducted with the sparging point operating at variable sparge pressures (e.g., 5 pounds per square inch-gauge [psig], 10 psig) and different depths (e.g., 5 feet, 10 feet below the dissolved phase plume). It is essential that vapor equilibrium be obtained prior to changing the sparge rate or depth. When no change in vapor emission rates from baseline occurs, the air sparging system may not be controlling the sparge vapor plume, possibly due to soil heterogeneity. Assess the potential for this problem by reviewing the site's soil lithology, typically documented on soil boring logs. During this test, the hydraulic gradient and VOC concentrations in soil vapors extracted from monitoring wells must be monitored until equilibrium is reached.

OK - Pilot WP emissions such test p. 3-7

The final portion of the pilot test is the concurrent operation of the SVE pilot system and the air sparging system. This portion of the test will determine the optimum SVE system (i.e., the number and orientation of wells) that will capture the sparged VOCs for various sparging rates. In addition, this portion of the test requires monitoring of VOC emissions, sparging pressure and flow rates, SVE vacuum and flow rates, monitoring well vapor concentrations, and dissolved constituent concentrations. Exhibit VII-13 presents a summary of the Pilot Test Data Objectives.

Evaluation Of The Air Sparging System Design

Once you have verified that air sparging is applicable to your site, you can evaluate the design of the system. The CAP should include a discussion of the rationale for the system design and the results of the pilot tests. Detailed engineering design documents might also be included, depending on individual state requirements. Discussion of the SVE portion of the design is included in Chapter II: Soil Vapor Extraction.

Rationale For The Design

The following factors should be considered as you evaluate the design of the air sparging system in the CAP.

- *Design ROI* for air sparging wells. The ROI is the most important parameter to be considered in the design of the air sparging system. The ROI is defined as the greatest distance from a sparging well at which sufficient sparge pressure and airflow can be induced to enhance the mass transfer of contaminants from the dissolved phase to the vapor phase. The ROI will help determine the number and spacing of the sparging wells.

Exhibit VII-13
Pilot Test Data Objectives

Data Requirement	Source
SVE Test Portion (if necessary)	
SVE radius of influence (ROI)	Monitoring point pressure gauges
Wellhead and monitoring point vacuum	Well head pressure gauge
Initial contaminant vapor concentrations	SVE exhaust flame ionization detector (FID) readings (or other suitable detection device)
Initial hydraulic gradient	Water level tape at monitoring wells or pressure transducers and data logger
Air Sparging Test Portion	
Air sparging ROI	Monitoring point pressure gauge
Sparging rate	Compressor discharge flow gauge
Sparging vapor concentrations	Monitoring well and vapor point FID readings (or other suitable detection device)
Hydraulic gradient influence	Water level tape at monitoring wells or pressure transducers and data logger
Dissolved oxygen and carbon dioxide	Dissolved oxygen and carbon dioxide probes at monitoring wells
Combined Test (if necessary)	
Sparging/SVE capture rates	Pressure/flow gauges
Constituent vapor concentrations	Blower discharge and monitoring points

The ROI should be determined based on the results of pilot tests. One should be careful, however, when evaluating pilot test results because the measurement of air flow, increased dissolved oxygen, or the presence of air bubbles in a monitoring point can be falsely interpreted as an air flow zone that is thoroughly permeated with injected air. However, these observations may only represent localized sparging around sparsely distributed air flow channels. The ROI depends primarily on the hydraulic conductivity of the aquifer material in which sparging takes place. Other factors that affect the ROI include soil heterogeneities, and differences between lateral and vertical permeability of the soils. Generally, the design ROI can range from 5 feet for fine-grained soils to 100 feet for coarse-grained soils.

- *Sparging Air Flow Rate.* The sparging air flow rate required to provide sufficient air flow to enhance mass transfer is site-specific and will be determined via the pilot test. Typical air flow rates range from 3 to 25 standard cubic feet per minute (scfm) per injection well. Pulsing of the air flow (i.e., turning the system on and off at specified intervals) may provide better distribution and mixing of the air in the contaminated saturated zone, thereby allowing for greater contact with the dissolved phase contaminants. The vapor extraction system should have a greater flow capacity and greater area of influence than the air sparging system. The air sparging rate should vary between 20 percent and 80 percent of the soil vapor extraction flow rate.

- *Sparging Air Pressure* is the pressure at which air is injected into the saturated zone. The saturated zone requires pressures greater than the static water pressure (1 psi for every 2.3 ft of hydraulic head) and the head necessary to overcome capillary forces of the water in the soil pores near the injection point. A typical system will be operated at approximately 10 to 15 psig. Excessive pressure may cause fracturing of the soils and create permanent air channels that can significantly reduce air sparging effectiveness.

- *Initial Constituent Vapor Concentrations* are measured during pilot studies. They are used to estimate constituent mass removal rates and system operational time requirements and to determine whether treatment of extracted vapors will be required prior to atmospheric discharge or reinjection.

- *Required Final Dissolved Constituent Concentrations* in the saturated zone will determine which areas of the site require treatment and when air sparging system operations can be terminated. These levels are usually defined by state regulations as *remedial action levels*. In some states, these levels are determined on a site-specific basis using transport modeling and risk assessment.

- *Required Remedial Cleanup Time* may influence the design of the system. The designer may vary the spacing of the sparging wells to speed remediation to meet cleanup deadlines, if required.

- *Saturated Zone Volume To Be Treated* is determined by state action levels or a site-specific risk assessment using site characterization data for the groundwater.

- *Pore Volume Calculations* are used along with extraction flow rate to determine the pore volume exchange rate. Some literature suggests that at a minimum one pore volume of soil vapor should be extracted daily for effective remedial progress.

- *Discharge Limitations And Monitoring Requirements* are usually established by state regulations but must be considered by designers of an air sparging system which uses SVE to ensure that monitoring ports are included in the system hardware. Discharge limitations imposed by state air quality regulations will determine whether offgas treatment is required.

- *Site Construction Limitations* (e.g., building locations, utilities, buried objects, residences) must be identified and considered in the design process.

5. Close inlet valve at wellhead;
6. Turn on vacuum blower and record the following information:
   a. Date;
   b. Time;
   c. Flow rate from extraction well;
   d. Vacuum at extraction well;
   e. Flow rate from blower discharge stack (should be equal to maximum blower flow rating when dilution air inlet valve is completely open);
   f. Oxygen, carbon dioxide, and methane concentrations in extracted vapor using a portable multi-gas detector;
   g. Organic vapor concentrations measured with a PID and/or FID;
   h. Vacuum in each vadose zone monitoring well;
   i. Flow rate in each vadose zone monitoring well;
   j. Depth to water in monitoring wells screened across the water table;
   k. Ambient barometric pressure;
   l. Ambient temperature; and
   m. Volume of condensate/sediment generated and pumped out of the air/water separator.

   If desired, collect an extraction vapor sample for laboratory analysis of VOCs. Open valve at wellhead;
7. Record data from 6a through 6m;
8. Slowly and partially close the dilution air inlet valve until the optimum vacuum is measured at the wellhead. Once vacuum and flow rate stabilizes (+/- 10%), record the data listed in 6a through 6m;
9. Continue recording the data identified in Task 6 periodically throughout the test. Note that depth to water, ambient barometric pressure, ambient temperature, and vapor sample collection will occur at less frequent intervals than other data collection;
10. The test will be conducted for a maximum of eight hours with the goal of extracting at least one pore volume of air. The time needed to extract one

pore volume of air can be estimated based on the ROI observed in the field and the optimum extraction flow rate; and

11. The volume of condensate and sediment generated during the test will be accumulated in 55-gallon drums(s). The total volume of sediment/condensate generated during the test will be monitored.

Following completion of the above Constant Rate Test, a graph of detectable air flow rates in the vadose zone monitoring wells versus the distance from the extraction well will be plotted. Using the plot, a desired operating ROI can be selected. The ROI will serve as a basis for designing the number and location of extraction wells needed in a full scale SVE system.

At least three vapor samples will be collected during the Constant Rate SVE Test and submitted to the laboratory for analysis of VOCs.

A Constant Rate SVE Test will be conducted separately at both extraction wells VE-1 and VE-2. The above procedure will be duplicated during each test using the aforementioned procedures.

AIR SPARGE (AS) TEST

The purpose of the AS Test is to determine the breakthrough air pressure (injection pressure) required to force air into the saturated soil formation, to observe water table changes (mounding) as a result of sparging, and to identify spatial geometry of vapor flow in the saturated zone using air and tracer gas (helium). The goal of the test is to identify the optimum sparge pressure based on the ROI observed. The optimum sparge pressure is needed to size an air compressor for the remedial design phase.

Prior to initiating the AS Test, groundwater samples will be collected from saturated zone wells AS-1, ASDM-1, ASDM-2, ASDM-3, and ASDM-4. Groundwater samples will be submitted for VOCs analysis. The AS Test will be conducted as follows:

1. Measure depth to water in the sparge well and the sparge monitoring wells.
2. Measure dissolved oxygen, pH, and oxidation-reduction potential (ORP) in groundwater in the sparge well and each monitoring well.
3. Connect air compressor to sparge well and prepare monitoring wells for the AS test such that vapor can be collected from the vadose zone.
4. Collect vadose zone gas samples from monitoring wells ASDM-1 through ASDM-4/VM-3D, VM-4D, and VM-5D for VOCs analysis. Record field measurements of organic vapor concentration in vadose zone using a PID and/or FID. Collect vadose zone gas for field measurement of percent oxygen and helium concentration.
5. Determine the hydrostatic head (feet) of water above the top of the well screen. Convert hydrostatic head to pounds per square inch (psi) by dividing the number of feet of water by 2.31. (2.31 feet of water = 1 psi).
6. Start air compressor and gradually increase the pressure of air delivered to the sparge well until breakthrough pressure is reached. Record the breakthrough pressure and the air flow rate. The breakthrough pressure is the minimum pressure required to force air into the soil matrix. The breakthrough pressure is typically a number slightly greater than the hydrostatic head calculated in Step 5.
7. The first of three sparge tests will be conducted at an approximate pressure of 1.2 times the hydrostatic head calculated in Step 5. Record the pressure and flow rate.
8. Inject helium gas at the same pressure as the compressed air.
9. During the test, record the following data and collect the following samples:
   a. Injected air flow rate;
   b. Injected helium flow rate;
   c. Pressure at the sparge well;
   d. Depth to water in monitoring wells;
   e. Field measurement of organic vapor (PID and/or FID) concentration, helium concentration, and percent oxygen in vadose zone gas;

f. Field measurement of dissolved oxygen, ORP, and pH in saturated zone; and

g. Pressure and flow induced in monitoring wells.

10. At the end of the test run (minimum of 45 minutes; maximum of 120 minutes per test run), record the data from Step 9 and collect vadose zone gas samples from monitoring wells ASDM-1 through ASDM-4/VM-3D through VM-5D for VOCs analysis.
11. Collect a groundwater sample from sparge wells screened in the saturated zone (ASDM-1 through ASDM-4) for VOCs analysis.
12. Conduct two additional test runs at two higher pressures of 1.5 and 2.0 times the hydrostatic head value calculated in Step 5. Repeat steps 9 through 11 as part of each test.
13. Stop sparge test.

Refer to Table 3.1 for a summary of samples collected during the AS Test.

COMBINED AS/SVE TEST

The purpose of the combined AS/SVE Test is to evaluate the effects of simultaneously operating both systems. Changes in SVE ROI due to air sparging, static water level changes, and VOC concentration changes will be evaluated.

In order to evaluate VOC concentrations, three extracted vapor samples will be collected during the combined test. The first vapor sample will be collected once the SVE system stabilizes and prior to AS startup. The second vapor sample will be collected near the beginning of the combined system operation. A third vapor sample will be collected prior to shut down of both the SVE and AS systems. Three extraction vapor samples will also be collected for field measurement of organic vapor concentration (PID and/or FID), helium concentration, and percent oxygen. The Combined AS/SVE Test will be conducted as follows:

1. Measure depth to water in the sparge well and the sparge monitoring wells.

2. Measure dissolved oxygen, pH, and ORP in groundwater from the sparge well and each sparge monitoring well.
3. Connect well head assemblies for extraction well, sparge well, and monitoring wells.
4. Start up SVE system and operate at the optimum vacuum identified during earlier Step Tests and Constant Rate Tests.
5. Record the vacuum and flow rate at the extraction well.
6. Record induced vacuum, flow rate, and depth to water (if present) in monitoring wells. Measure dissolved oxygen, pH, and ORP in groundwater from each sparge monitoring wells.
7. After stabilization of the vacuum and flow rate in the extraction well and monitoring wells is observed, start up the AS system by injecting air at the optimum sparge pressure identified during AS Test. (No helium injection is needed.)
8. Record data from 5 and 6 above plus applied sparge pressure and sparge air flow rate.
9. If positive pressure is observed in monitoring wells, increase extraction vacuum.

Two combined tests will be conducted. The first will consist of air sparging and vapor extraction from well VE-1. The second will consist of air sparging and vapor extraction from well VE-2.

Table 3.1 summarizes the soil gas and groundwater samples to be collected during Pilot Testing.

TABLE 3.1
Samples Collected During Pilot Test

	Groundwater – VOCs		Soil Gas – VOCs	
Time of Collection	Field	QC[(1)]	Field	QC[(2)]
During SVE Step Test (VE-1)	--	--	2	1
During SVE Step Test (VE-2)	--	--	2	1
During Constant Rate SVE Test (VE-1)	--	--	3	1
During Constant Rate SVE Test (VE-2)	--	--	3	1
Prior to Start of AS Test	5	1	7	1
AS Test (End of Run 1)	4	--	7	--
AS Test (End of Run 2)	4	--	7	--
AS Test (End of Run 3)	4	--	7	--
Combined AS/SVE Test using VE-1 (prior to AS Startup)	--	--	1	1
Combined AS/SVE Test using VE-1 (near beginning of combined operation)	--	--	1	--
Combined AS/SVE Test using VE-1 (prior to Shutdown)	--	--	1	--
Combined AS/SVE Test using VE-2 (prior to AS Startup)	--	--	1	1
Combined AS/SVE Test using VE-2 (near beginning of combined operation)	--	--	1	--
Combined AS/SVE Test using VE-2 (prior to Shutdown)	--	--	1	--
Upon completion of Pilot Test Program	5	1	--	--
TOTAL SAMPLES	22	2	44	7

(1) Groundwater QC samples include one rinse blank, one duplicate, one MS/MSD, and one trip blank.

(2) Soil Gas QC samples include one field blank and one trip blank.

SECTION 4.0

FIELD DATA COLLECTION

VACUUM MEASUREMENTS

Magnehelic® vacuum gauges will be utilized for field vacuum measurements. A fixed gauge will be located between the extraction wellhead and the air/water separator on the SVE unit. In addition, each monitoring well will be equipped with a sealed cap having a quick connection for vacuum gauge attachment.

EXTRACTION WELL VAPOR FLOW RATE

The vapor flow rate at the extraction well will be determined by using a thermal anemometer. In the alternative or as a backup method, velocity pressure may be measured with a pitot tube and Magnehelic® pressure gauge. If a pitot tube is used, the air velocity will then be obtained either from a direct reading of the velocity from a dual scale pressure gauge or from a pitot tube manufacturer-provided graph of air velocity versus velocity pressure. The air velocity is then multiplied by the cross-sectional area of the pipe to obtain the flow rate in scfm. For a 2- inch inner diameter (I.D.) pipe, the cross sectional area of the pipe is 0.0218 ft^2. The calculated flow rate must then be adjusted to acfm by correcting for field barometric pressure and temperature conditions.

AIR FLOW RATES AT MONITORING WELLS

Air flow rates at monitoring wells will be measured using SKC Dual Ball Rotometers or equivalent. Tubing from the monitoring well will be connected to the top of the rotometer. Rotometer readings, typically in liters per minute, will then be converted to scfm by multiplying the liters per minute by 0.03531 (ft^3/liter). Again, this scfm measurement must be converted to acfm by correcting for actual barometric pressure and temperature conditions.

DEPTH TO WATER MEASUREMENTS

The depth to water in monitoring wells screened within the saturated zone will be measured with a water level meter capable of measuring to the nearest 0.01 feet.

CARBON DIOXIDE, OXYGEN, AND METHANE LEVELS IN VAPOR

Carbon dioxide, oxygen, and methane concentrations in extracted vapor will be measured with an RKI EAGLE™ portable multi-gas detector, or equivalent. Grab samples of vapor will be drawn into a Tedlar bag connected to a sample port but located inside an evacuation chamber (vacuum box). An evacuation pump will be used to evacuate the vacuum box, causing sample to be drawn into the sample bag. The sample bag will then be disconnected from the vacuum box and reconnected to a hose attached to the RKI EAGLE™ to obtain field measurements for carbon dioxide, oxygen, and methane.

ORGANIC VAPOR CONCENTRATIONS IN VAPOR

Organic vapor concentrations in extracted vapor will be measured with a Foxboro TVA 1000 Dual FID/PID, or equivalent. The PID will be equipped with a 10.6 eV lamp. Vapor samples will be drawn into a Tedlar bag located within a vacuum box prior to field screening of the gas with the FID/PID.

HELIUM TRACER GAS CONCENTRATION

Helium gas will be injected along with air during the AS Pilot Test. Helium concentrations in vapor samples collected from vadose zone monitoring wells will be measured with a Mark Products Model 9822™ helium detector, or equivalent. Vapor samples will be drawn into a Tedlar bag located within a vacuum box prior to field screening of the gas with the helium detector.

DISSOLVED OXYGEN, OXIDATION-REDUCTION POTENTIAL (ORP), AND pH IN GROUNDWATER

Dissolved oxygen, ORP, and pH measurements of groundwater will be measured with a Horiba U-series water quality instrument, or equivalent. A flow cell may be employed for sampling, particularly during the AS testing when several groundwater sampling events are proposed.

SECTION 5.0

SAMPLE COLLECTION

The following section summarizes the data collection and sampling methods for soil vapor sampling from vadose zone monitoring wells and groundwater sampling from groundwater monitoring wells.

SOIL VAPOR SAMPLING

A total of forty-four (44) vapor samples will be collected for VOCs analysis. Fourteen (14) extracted vapor samples from the extraction well will be collected during SVE Step Tests, Constant Rate SVE Tests, and Combined AS/SVE Tests. Twenty-eight (28) vapor samples will be collected from vadose zone monitoring wells during the AS Tests.

GROUNDWATER SAMPLING

In accordance with the Field Sampling Plan, twenty-two (22) groundwater samples will be collected as part of the Pilot Test Program. Each groundwater sample will be submitted to the laboratory for VOCs analysis using SW-846 Method 8260B.

Prior to sampling pilot study monitoring wells, depth to water measurements will be taken at each individual well. Samples will be collected using bailers or down hole submersible pumps with dedicated Teflon or Teflon-coated polyethylene tubing. If a submersible pump is utilized, a flow cell may be used for field measurement of pH, temperature, conductivity, dissolved oxygen, and ORP. VOC samples will be collected by slowly pumping the sample into 40-ml glass vials. Vials will be filled until a convex meniscus is present, and then capped. The cap will then be secured and checked for trapped air. Any samples with entrained air will be discarded, and new samples collected. Duplicate and field blank samples will also be collected in accordance with the Quality Assurance Project Plan.

SECTION 6.0

ANALYTICAL METHODOLOGIES AND NUMBER OF SAMPLES

This section presents a description of the laboratory analytical methods and required sample containers to be used for the collection and analysis of groundwater and soil gas samples during Pilot Testing.

ANALYTICAL PARAMETERS

Groundwater samples associated with the AS Test and the combined AS/SVE Test will be analyzed for VOCs using USEPA 8260B. In addition, condensate and sediment accumulated during the testing activities will be analyzed for waste characterization. A summary of the sample numbers, matrices, and methodology is presented on Table 6.1. Sample containers, necessary preservation(s), and holding times for the analytical methods are listed on Table 6.2.

TABLE 6.1
Samples Collected by Matrix as Part of Pilot Study

	Groundwater[1]		IDW[2]	Soil Gas	
Parameters	Field	QC	Sediment/Water	Field	QC
SW846 Method 8260B (VOCs)	22	2	2	--	--
Method 18/TO-15 (VOCs)	--	--	--	44	7

Foot Note:

(1) 40 ml VOA vials will be laboratory preserved with HCl acid.

(2) IDW samples will be collected at a minimum of one sample per drum of sediment/condensate generated during the Pilot Test.

(3) Groundwater QC samples include one rinse blank, one duplicate, one MS/MSD, and one trip blank.

TABLE 6.2 Sample Containers, Preservatives, & Holding Times				
Matrix	Parameter/ Analytical Method	Sample Container	Preservative	Holding Time To Extraction
Groundwater	VOCs (5030B/8260B)	40 ml glass vials	HCl; pH <2 Cool, 4 +/- 2°C	14 Days
Soil Gas	VOCs (Method 18/TO-15)	Tedlar Bags (1.0 L)	--	72 hrs*; 28 Days

* Soil gas samples must be shipped to the laboratory each day for overnight delivery. Upon receipt, the laboratory will transfer the samples to Summa® canisters, increasing the hold time to 28 days.

SECTION 7.0

DATA ANALYSIS, INTERPRETATION, AND REPORTING

Upon completion of the Pilot Tests, a Pilot Test Summary Report (PTSR) will be prepared. The PTSR will present the data gathered, highlight Pilot Test findings, and identify data gaps, if any, requiring further evaluation and analysis. A discussion of the design parameters formulated as a result of the Pilot Test will be presented.

If deemed appropriate, AS/SVE screening software such as Hyperventilate (USEPA, 1993) or equivalent, may be used as a reference model to support Pilot Test findings. Although the modeling software will assist in data evaluation, Pilot Test findings will be relied upon to support the design process.

(nothing in literature mentions this software

The PTSR will discuss the ability of AS/SVE to meet stated remedial goals based on the technical data gathered.

APPENDIX A TO PILOT TEST WORK PLAN
HISTORIC BORING LOGS/WELL CONSTRUCTION DIAGRAMS

SECOR Project NO.: 13UN.02072.01.0001
July 3, 2003

APPENDIX A

TABLE OF CONTENTS

MAJOR DIVISIONS					TYPICAL NAMES
COARSE-GRAINED SOILS MORE THAN HALF IS LARGER THAN No. 200 SIEVE	GRAVELS MORE THAN HALF COARSE FRACTION IS LARGER THAN No. 4 SIEVE SIZE	CLEAN GRAVELS WITH LITTLE OR NO FINES	GW		WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES
			GP		POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES
		GRAVELS WITH OVER 12% FINES	GM		SILTY GRAVELS, POORLY GRADED GRAVEL-SAND-SILT MIXTURES
			GC		CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES
	SANDS MORE THAN HALF COARSE FRACTION IS SMALLER THAN No. 4 SIEVE SIZE	CLEAN SANDS WITH LITTLE OR NO FINES	SW		WELL-GRADED SANDS, GRAVELLY SANDS
			SP		POORLY GRADED SANDS, GRAVELLY SANDS
		SANDS WITH OVER 12% FINES	SM		SILTY SANDS, POORLY GRADED SAND-SILT MIXTURES
			SC		CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES
FINE-GRAINED SOILS MORE THAN HALF IS SMALLER THAN No. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT 50% OR LESS		ML		INORGANIC SILTS AND VERY FINE SANDS ROCK FLOUR, SILTY OR CLAYEY FINE SANDS, OR CLAYEY SILTS WITH SLIGHT PLASTICITY
			CL		INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL		ORGANIC CLAYS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50%		MH		INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
			CH		INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH		ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS			Pt		PEAT AND OTHER HIGHLY ORGANIC SOILS

UNIFIED SOIL CLASSIFICATION SYSTEM

■ - "Undisturbed" S&H or Shelby tube sample

⊠ - Standard Split Spoon or Bulk Sample

I - Core sample

□ - Sample not recovered

Blows/ft - Blows required to drive sampler 12 inches with a 140-pound hammer falling 30 inches. Blow counts for S&H samplers are converted to approximate "equivalent" SPT N values (N = 0.5 X S&H blows per foot). P = Push

▽ - Unstabilized Groundwater Level

▼ - Stabilized Groundwater Level

PID - Photoionization Detector reading (10.2-electron-volt lamp, calibrated using an isobutylene standard)

FID - Flame Ionization Detector head-space reading (calibrated to a methane standard)

Lab Test:

CH - Sample submitted for chemical analysis

GT - Sample submitted for geotechnical analysis

KEY TO BORING LOG

Harding Lawson Associates
Engineering and
Environmental Services

Soil Classification Chart
& Key to Test Data
Plant #2 - Outside Storage Area
Sundstrand Aerospace, Rockford, Illinois

PLATE
B1

DRAWN	PROJECT NUMBER	APPROVED	DATE	REVISED DATE
EWS	20170,5.1		08/92	

Boring No. VE-1

Equipment: A210: HSA

Elevation: 99 ft   Date: 6/16/92

Top of Casing: NA

See Pl. B20 for Wellhead Const.
Bentonite Cement Grout
Bentonite Pellet Seal
2" dia. Blank PVC Casing
Washed Silica Sand
2" dia. Slotted Casing (0.010 Slots)
Bottom Cap
Hydrated Bentonite Chips

FID-(ppm)	Blows/ft	Lab Test
213		CH
	20	
		GT
51	15	
42	7	CH

Depth ft: 0, 5, 10, 15

CONCRETE - 5 inches

LIGHT BROWN SANDY GRAVEL (GP) [FILL]
medium dense, moist, strong odors, stained

BLACK CLAYEY SAND (SC) [FILL]
medium dense, moist, very fine to fine sand grains, trace gravel, stained, strong odors

LIGHT BROWN SAND (SP)
loose, moist, fine gravel, strong odors

LIGHT BROWN GRAVELLY SAND (SP)
loose, moist, very fine to medium grained sand, trace silt, gravel up to 1.0 inches, slight odor

Boring terminated at 6.0 feet.
Groundwater not encountered during drilling.
Boring converted to vadose zone well at 4.5 feet on 6-16-92.
Borehole elevation is approximate, and relative to other borings.

Boring No. VE-2

Equipment: A210: HSA

Elevation: 99 ft   Date: 6/17/92

Top of Casing: NA

See Pl. B20 for Wellhead Const.
Bentonite Cement Grout
Bentonite Pellet Seal
2" dia. Blank PVC Casing
Washed Silica Sand
2" dia. Slotted Casing (0.010 Slots)
Bottom Cap
Hydrated Bentonite Chips

FID-(ppm)	Blows/ft	Lab Test
	21	
1850	9	CH
220	8	

Depth ft: 0, 5, 10, 15

CONCRETE - 4.5 inches

LIGHT BROWN SANDY GRAVEL (GP) [FILL]
medium dense, moist, fine to medium grained sand, gravel up to 1.0 inches

BLACK CLAYEY SAND (SC) [FILL]
loose, moist, very fine to fine grained sand, trace gravel up to 0.2 inches, stained black, with strong odors

LIGHT BROWN SILTY SAND (SM)
loose, moist, very fine to medium grained sand, trace gravel up to 0.2 inches

Boring terminated at 6.0 feet.
Groundwater not encountered during drilling.
Boring converted to vadose zone well at 4.5 feet on 6-17-92.
Borehole elevation is approximate, and relative to other borings.

Harding Lawson Associates
Engineering and Environmental Services

Log of Borings

Sundstrand OSA Plant 2
Rockford, Illinois

PLATE B2

DRAWN TAK | PROJECT NUMBER 20170.21 | APPROVED [signature] | DATE 8/92 | REVISED DATE

Top of Casing NA

Equipment A210: HSA

Elevation 99 ft Date 6/17/92

See Plate B22 for Wellhead Construction

Bentonite Cement Grout

2" dia. Blank PVC Casing

Bentonite Pellet Seal

Washed Silica Sand

2" dia. Slotted PVC Casing (0.010 Slots)

Bottom Cap

Hydrated Bentonite Chips

FID-(ppm)	Blows/ft	Lab Test
	17	
	4	GT
	4	
0	4	CH
0		
	20	
0		
	13	
0		
	19	
0	21	GT
0		
	18	
0		CH
	22	
0		
	47	
	35	
0		
	25	
0		CH
	72	
	24	
	29	

Depth ft: 0, 5, 10, 15, 20, 25, 30, 35, 40

CONCRETE - 4.5 inches

LIGHT BROWN SANDY GRAVEL (GP)[FILL]
medium dense, moist, with silt, fine to medium grained sand, gravel up to 1.0 inches

BLACK CLAYEY SAND (SC) [FILL]
loose to medium dense, moist, very fine to fine sand, trace clay and gravel up to 1.0 inches

DARK TO LIGHT BROWN CLAYEY SAND (SC) [FILL]
loose, moist, very fine to medium grained sand, trace clay

LIGHT BROWN SANDY GRAVEL (GP)
loose, moist, fine to coarse sand, gravel up to 0.2 inches

LIGHT BROWN SILTY SAND (SM)
loose, moist, fine to medium grained sand, trace gravel

LIGHT BROWN SAND (SP)
medium dense, moist, fine to medium grained sand, trace very fine sand, well rounded sand grains, trace gravel up to 1.0 inches.

YELLOW-BROWN SANDY SILT (ML)
stiff, moist, very fine grained sand

LIGHT BROWN SAND (SP)
medium dense, moist, fine to medium grained sand

LIGHT BROWN SAND (SP)
very dense, moist, fine to coarse grained sand, little gravel up to 2.0 inches

medium dense, wet at 32.6 feet

Boring terminated at 35.0 feet.
Groundwater encountered at 33.5 feet during drilling; static groundwater measured at 33.5 feet at 1243 (before augers pulled) on 6-17-92.
Boring backfilled to 19.0 feet with bentonite chips; hydrated every 5.0 feet with 4 gallons of water on 6-17-92.
Elevation is approximate, and relative to other borings.

Harding Lawson Associates
Engineering and Environmental Services

Log of Boring VE- 3

(sheet 1 of 1)

Sundstrand OSA Plant 2
Rockford, Illinois

PLATE **B3**

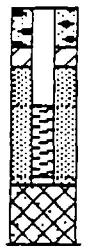
DRAWN	PROJECT NUMBER	APPROVED	DATE	REVISED DATE
TAK	20170.21	GT	8/92	

Boring No.	VE- 4		
Equipment	A210: HSA		
Elevation	99 ft	Date	6/17/92

Top of Casing NA

See Pl. B20 for Wellhead Const.
Bentonite Cement Grout
Bentonite Pellet Seal
2" dia. Blank PVC Casing
Washed Silica Sand
2" dia. Slotted Casing (0.010 Slots)
Bottom Cap

Hydrated Bentonite Chips



FID-(ppm)	Blows/ft	Lab Test
1842	10	CH
1650	6	GT
1190	7	

Depth ft: 0, 5, 10, 15

Sample

CONCRETE - 4.75 inches

LIGHT BROWN SAND (SP) [FILL]
loose, moist, coarse grained sand, little gravel

DARK BROWN CLAYEY SAND (SC) [FILL]
loose, moist, fine sand grains, trace gravel

BLACK CLAYEY SAND (SC) [FILL]
loose, moist to wet, trace fine sand grains, some odor

DARK BROWN SILTY SAND (SM)
loose, moist, trace to little gravel up to 1.0 inch from 5.5 feet to 6.0 feet
changing to light brown at 5.0 feet

Boring terminated at 6.0 feet.
Groundwater not encountered during drilling.
Boring converted to vadose zone well at 4.5 feet on 6-17-92.
Borehole elevation is approximate, and relative to other borings.

Harding Lawson Associates
Engineering and Environmental Services

Log of Borings
Sundstrand OSA Plant 2
Rockford, Illinois

PLATE B4

DRAWN	PROJECT NUMBER	APPROVED	DATE	REVISED DATE
TAK	20170.21	GH	8/92	

Top of Casing NA

Equipment Acker Soilmax

Elevation 100 ft Date 6/18/92

Well construction

See Plate B21 for Wellhead Construction

Bentonite Cement Grout

2" dia. Blank PVC Casing

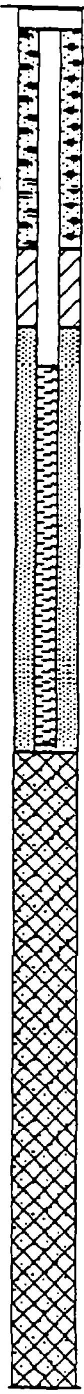
Bentonite Pellet Seal

Washed Silica Sand

2" dia. Slotted PVC Casing (0.010 Slots)

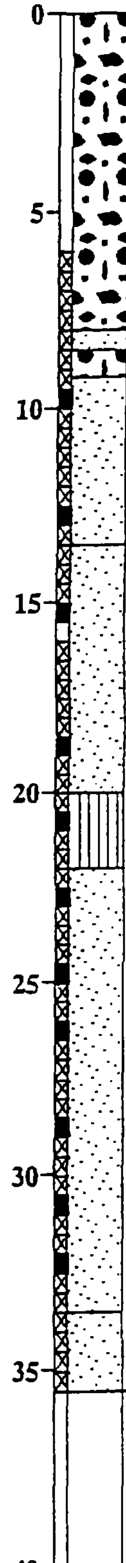
Bottom Cap

Hydrated Bentonite Chips



FID-(ppm)	Blows/ft	Lab Test
137	5 14	
720	24 26	CH
155	31	
16	14	
	18	GT
2	25	CH
0	41	
1	49	CH
0	39	
38	45	CH
17	26	
	22	

Depth ft / Sample



GRAVEL (GP) [FILL]
pea gravel

blind drill through gravel backfill to 6.0 feet

LIGHT BROWN SAND (SP) [FILL]
loose, moist, some silt, trace gravel up to 1.0 inch

LIGHT BROWN SANDY GRAVEL (GP) [FILL]
loose, moist

LIGHT BROWN SAND (SP)
medium dense, moist, fine to medium grained sand, trace to little gravel

LIGHT BROWN SAND (SP)
dense to medium dense, moist, fine to medium grained sand, trace gravel

YELLOW-BROWN SILT (ML)
very stiff, wet, with sand

LIGHT BROWN SAND (SP)
medium dense to dense, moist, fine to medium grained sand, trace gravel up to 2 inches

wet at 33.0 feet

LIGHT BROWN SAND (SP)
medium dense, wet, fine to medium grained sand, some coarse sand, trace gravel

Boring terminated at 35.5 feet.
Groundwater encountered at 34.5 feet during drilling; stabilized groundwater level not measured.
Boring converted to vadose zone well at 19.0 feet on 6-18-92.
Borehole elevation is approximate, and relative to other borings.

Harding Lawson Associates
Engineering and Environmental Services

Log of Boring VE- 5

(sheet 1 of 1)

Sundstrand OSA Plant 2
Rockford, Illinois

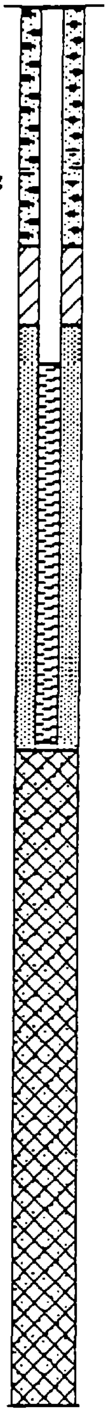
PLATE
B5

DRAWN	PROJECT NUMBER	APPROVED	DATE	REVISED DATE
TAK	20170.21		8/92	

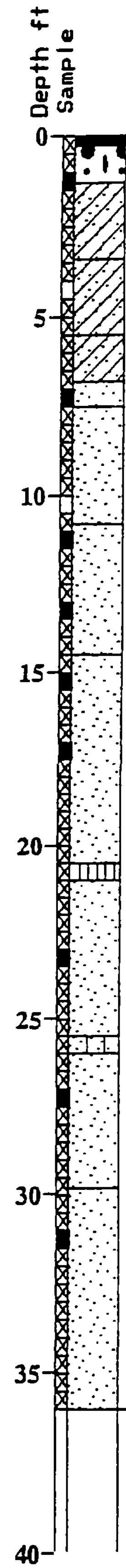
Top of Casing NA

Equipment Acker Soilmax

Elevation 100 ft Date 6/19/92



FID-(ppm)	Blows/ft	Lab Test
11	24	CH
	7	
16	7	
6	12	
7	31	
6	49	GT
11	38	
11	20	
15	18	CH
9	29	
17	15	
7	23	CH
9	21	
5	22	
7	38	
5	29	CH
13	21	
9	20	



ASPHALT - 1.5 inches

LIGHT BROWN SANDY GRAVEL (GP) [FILL]
medium dense, moist, fine to medium grained sand, gravel to 1.0 inch

DARK BROWN-BLACK CLAYEY SAND (SC) [FILL]
loose, moist, fine to medium grained sand, with cinders, trace clay

BLACK CLAYEY SAND (SC) [FILL]
medium stiff, moist, fine to medium grained sand, trace gravel up to 0.5 inches

BROWN SILTY CLAYEY SAND (SC)
stiff, moist, fine to medium grained sand, trace gravel up to 0.2 inches

LIGHT BROWN SAND (SP)
medium dense, moist, fine to coarse grained sand, trace coarse sand

LIGHT BROWN SAND (SP)
dense, moist, fine to medium grained sand

LIGHT BROWN SAND (SP)
dense, moist, medium grained sand, some coarse sand and gravel up to 0.5 inches

LIGHT BROWN SAND (SP)
medium dense, moist, fine to medium grained sand, well rounded sand grains

LIGHT BROWN SANDY SILT (ML)
stiff, moist to wet, very fine grained sand, some trace clay

LIGHT BROWN SAND (SP)
medium dense, moist, fine to medium grained sand, well rounded sand grains

LIGHT BROWN SILTY SAND (SM)
medium dense, wet, very fine grained sand, trace clay

LIGHT BROWN SAND (SP)
medium dense to dense, moist to wet, fine to medium grained sand, well rounded sand grains

medium to coarse grained sand from 29.25 feet to 29.75 feet

LIGHT BROWN SAND (SP)
medium dense, moist, fine to medium grained sand, some coarse sand, some gravel up to 0.75 inches

wet at 33.6 feet

Boring terminated at 36.0 feet; converted to vadose zone well at 19.0 feet on 6-19-92.

Groundwater encountered at 35.25 feet during drilling; stabilized groundwater level not measured.
Boring backfilled to 19.0 ft with bentonite chips; hydrated every 5.0 feet with 4 gallons of water on 6-17-92.
Borehole elevation is approximate, and relative to other borings.

Harding Lawson Associates
Engineering and Environmental Services

Log of Boring VE- 7 (sheet 1 of 1)

Sundstrand OSA Plant 2
Rockford, Illinois

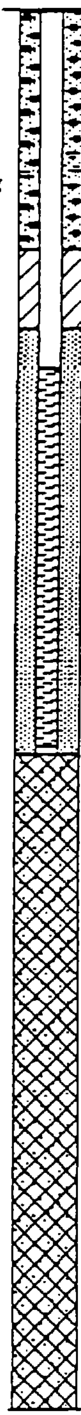
PLATE **B7**

DRAWN	PROJECT NUMBER	APPROVED	DATE	REVISED DATE
TAK	20170.21		8/92	

Top of Casing NA

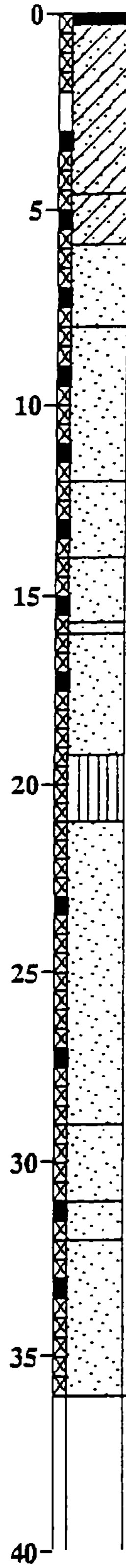
Equipment Acker Soilmax

Elevation 100 ft   Date 6/22/92



FID-(ppm)	Blows/ft	Lab Test
16	17	
82	9	CH
	8	
22	15	
21	8	CH
14	5	
11	28	
11	15	
6	19	CH
8	19	
6	28	
0	19	
0	27	
1	21	CH
1	28	
1	16	
4	38	
	17	

Depth ft / Sample



ASPHALT - 2 inches

DARK BROWN TO BLACK CLAYEY SAND (SC) [FILL]
medium dense, moist, with gravel up to 1.0 inch, some cinders

DARK BROWN CLAYEY SAND (SC) [FILL]
loose, moist, with silt, trace gravel

RED-BROWN SAND (SP)
medium dense, moist, fine to coarse grained sand, some gravel

RED-BROWN SAND (SP)
loose to medium dense, moist, fine to medium grained sand, trace gravel

LIGHT BROWN GRAVELLY SAND (SP)
medium dense, moist, gravel up to 1.0 inches

LIGHT BROWN SAND (SP)
medium dense, moist, fine to medium grained sand, trace fine gravel

BLACK TO LIGHT BROWN SAND (SP)
medium dense, moist, fine to coarse grained sand, some fine gravel

LIGHT BROWN SAND (SP)
medium dense, moist, fine to medium grained sand, trace fine gravel, lower foot has no gravel

LIGHT BROWN SANDY SILT (ML)
stiff, moist, very fine grained sand

LIGHT BROWN SAND (SP)
medium dense, moist, fine to medium grained sand, trace gravel up to 1.0 inches

LIGHT BROWN SAND (SP)
medium dense, moist, fine to coarse grained sand, little gravel up to 2.0 inches

LIGHT BROWN SAND (SP)
dense to medium dense, moist, fine to medium grained sand, little coarse sand, trace fine gravel

LIGHT BROWN SAND (SP)
dense to medium dense, moist, trace to little fine gravel up to 1.5 inches
wet at 35.0 feet

Boring terminated at 36.0 feet.

Groundwater encountered at 35.25 feet during drilling; stabilized groundwater not measured.
Boring converted to vadose zone well on 6-22-92.
Boring backfilled to 9.0 feet with bentonite chips; hydrated every 5.0 feet with 4 gallons of water on 6-22-92.
Elevation is approximate, and relative to other borings.

Harding Lawson Associates
Engineering and Environmental Services

Log of Boring VE- 9

(sheet 1 of 1)

Sundstrand OSA Plant 2
Rockford, Illinois

PLATE B9

DRAWN	PROJECT NUMBER	APPROVED	DATE	REVISED DATE
TAK	20170.21	GA	8/92	

APPENDIX B TO PILOT TEST WORK PLAN
EQUIPMENT SPECIFICATIONS

SECOR Project NO.: 13UN.02072.01.0001
July 3, 2003

APPENDIX B

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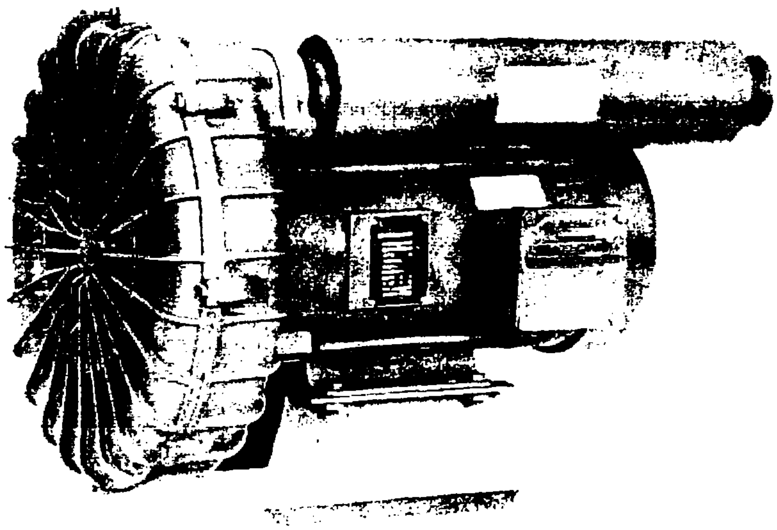
EN 6 & CP 6
Sealed Regenerative Blower w/Explosion-Proof Motor

FEATURES
- Manufactured in the USA – ISO 9001 compliant
- Maximum flow: 225 SCFM
- Maximum pressure: 104 IWG
- Maximum vacuum: 85 IWG
- Standard motor: 5.0 HP, explosion-proof
- Cast aluminum blower housing, cover, impeller & manifold; cast iron flanges (threaded); teflon lip seal
- UL & CSA approved motor with permanently sealed ball bearings for explosive gas atmospheres Class I Group D minimum
- Sealed blower assembly
- Quiet operation within OSHA standards

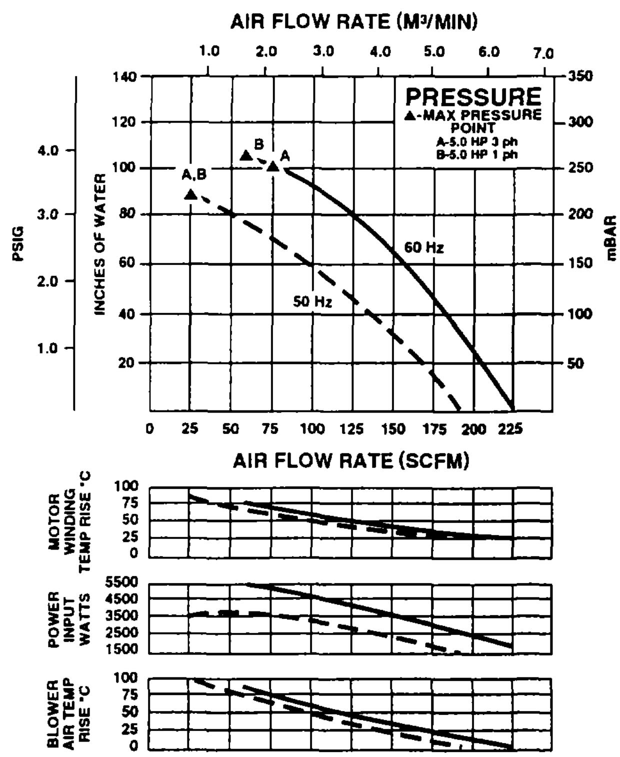
MOTOR OPTIONS
- International voltage & frequency (Hz)
- Chemical duty, high efficiency, inverter duty or industry-specific designs
- Various horsepowers for application-specific needs

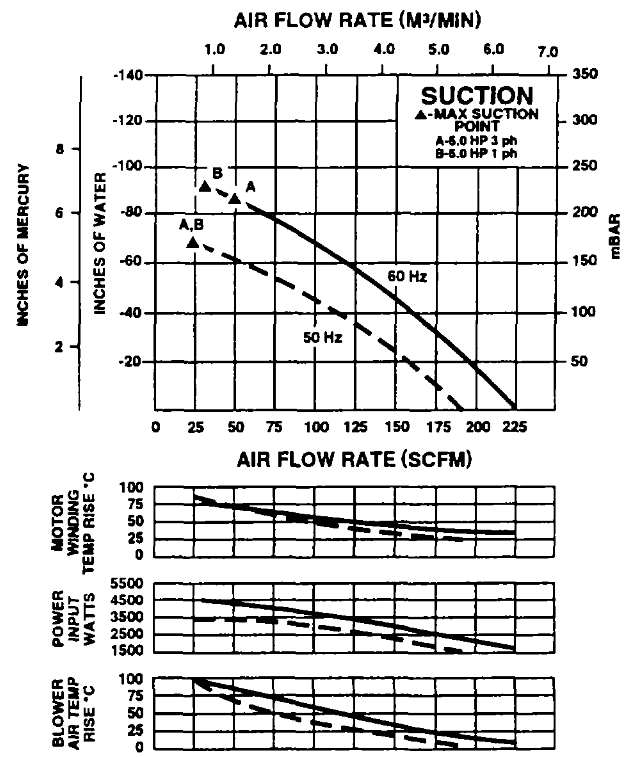
BLOWER OPTIONS
- Corrosion resistant surface treatments & sealing opti
- Remote drive (motorless) models
- Slip-on or face flanges for application-specific needs

ACCESSORIES (See Catalog Accessory Section)
- Flowmeters reading in SCFM
- Filters & moisture separators
- Pressure gauges, vacuum gauges & relief valves
- Switches – air flow, pressure, vacuum or temperatur
- External mufflers for additional silencing
- Air knives (used on blow-off applications)
- Variable frequency drive package



BLOWER PERFORMANCE AT STANDARD CONDITIONS

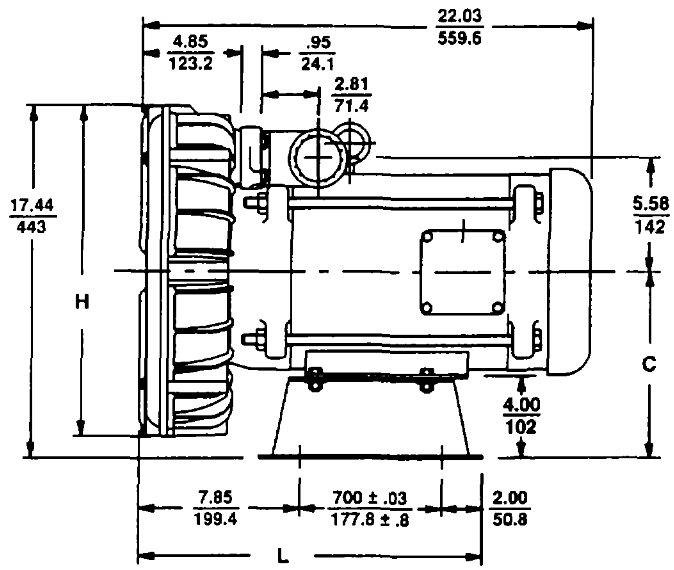


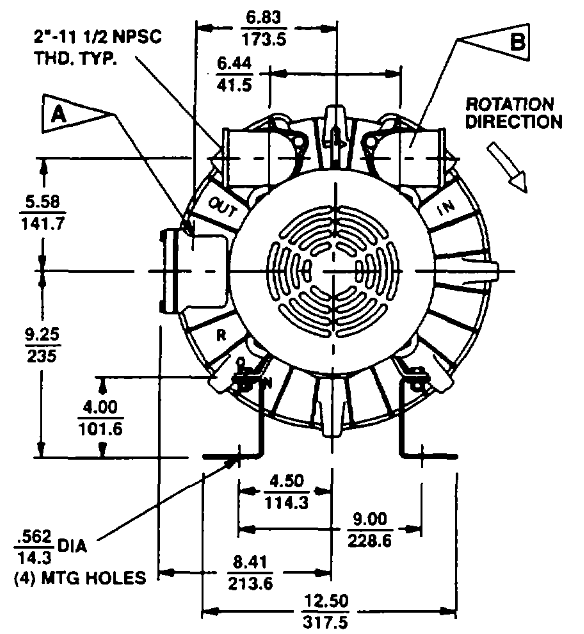


Rev. 2/01

EN 6 & CP 6
Sealed Regenerative Blower w/Explosion-Proof Motor

Scale CAD drawing available upon request.





DIMENSIONS: IN/MM
TOLERANCES: .XX ± .12/3
(UNLESS OTHERWISE NOTED)

MODEL	L (IN/MM)	C (IN/MM)	H (IN/MM)
EN/CP6F72L	20.37/517	8.5/216	16.7/424
EN/CP6F5L	22.0/560	10.21/259	17.5/443

A — 0.75" NPT CONDUIT CONNECTION AT 12 O'CLOCK POSITION

B — 90° ELBOW SUPPLIED ON 1 PHASE MODEL ONLY

SPECIFICATIONS

ALL PRODUCTS LISTED INCLUDE MUFFLER PN 522948

MODEL	EN6F5L	EN6F72L		EN6F86L	CP6FW5LR	CP6FW72LR
Part No.	038361	038180		038438	–	038978
Motor Enclosure – Shaft Material	Explosion-proof – **CS**	Explosion-proof – **CS**		Explosion-proof – **CS**	Chem XP – **SS**	Chem XP – **SS**
Horsepower	5.0	5.0		5.0	Same as EN6F5L – 038361 except add Chemical Processing (CP) features from catalog inside front cover	Same as EN6F72L – 038180 except add Chemical Processing (CP) features from catalog inside front cover
Phase – Frequency [1]	Single - 60 Hz	Three - 60 Hz		Three - 60 Hz		
Voltage [1]	230	230	460	575		
Motor Nameplate Amps	19.5	14	7	5.7		
Max. Blower Amps [3]	23	15.8	7.9	6.3		
Inrush Amps	175	152	76	38		
Starter Size	2	1	0	0		
Service Factor	1.0	1.0		1.0		
Thermal Protection [2]	Class B - Pilot Duty	Class B - Pilot Duty		Class B - Pilot Duty		
XP Motor Class – Group	I-D	I-D, II-F&G		I-D, II-F&G		
Shipping Weight	232 lb (105 kg)	160 lb (73 kg)		160 lb (73 kg)		

[1] Rotron motors are designed to handle a broad range of world voltages and power supply variations. Our dual voltage 3 phase motors are factory tested and certified to operate on both: **208-230/415-460 VAC-3 ph-60 Hz** and **190-208/380-415 VAC-3 ph-50 Hz.** Our dual voltage 1 phase motors are factory tested and certified to operate on both: **104-115/208-230 VAC-1 ph-60 Hz** and **100-110/200-220 VAC-1 ph-50 Hz.** All voltages above can handle a ±10% voltage fluctuation. Special wound motors can be ordered for voltages outside our certified range.

[2] Maximum operating temperature: Motor winding temperature (winding rise plus ambient) should not exceed 140°C for Class F rated motors or 120°C for Class B rated motors. Blower outlet air temperature should not exceed 140°C (air temperature rise plus inlet temperature). Performance curve maximum pressure and suction points are based on a 40°C inlet and ambient temperature. Consult factory for inlet or ambient temperatures above 40°C.

[3] Maximum blower amps corresponds to the performance point at which the motor or blower temperature rise with a 40°C inlet and/or ambient temperature reaches the maximum operating temperature.

Specifications subject to change without notice. Please consult your Local Field Sales Engineer for specification updates. Rev. 2/01

MOYNO

Always the Right Solution™

SPECIFICATION DATA

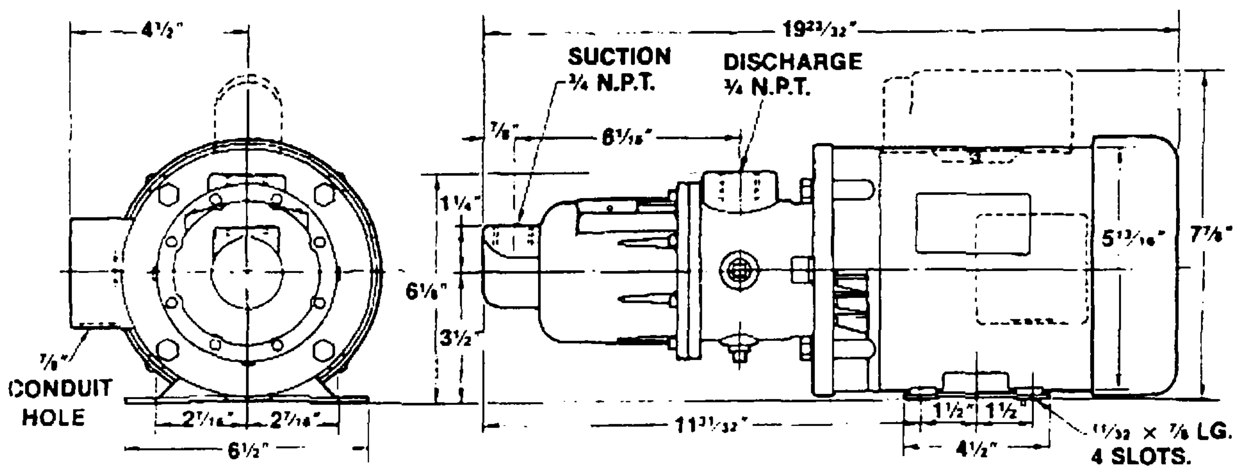
MOYNO® 500 PUMPS

300 SERIES MOTORIZED

331, 332, 333, 344, 356 AND 367 MODELS

331, 332, 333, 344 MODELS

DIMENSIONS

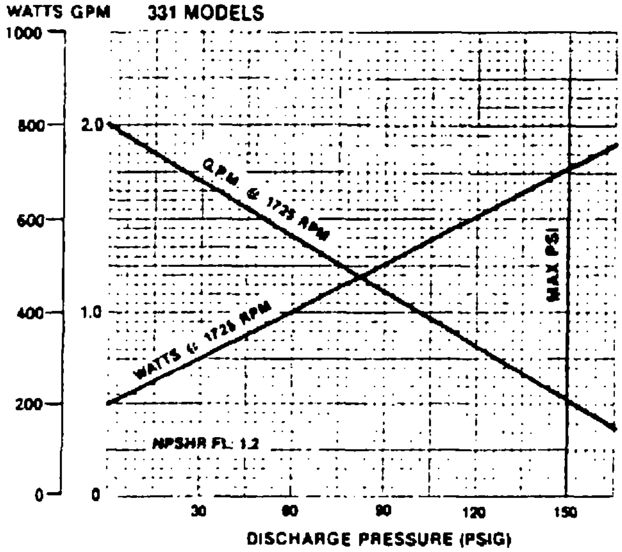


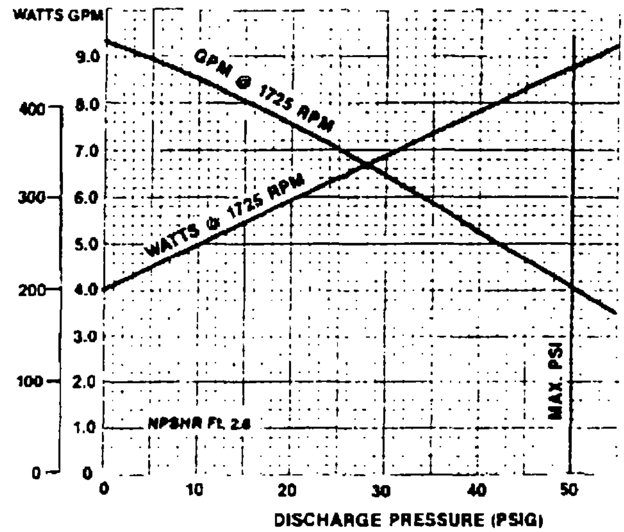
MATERIALS OF CONSTRUCTION

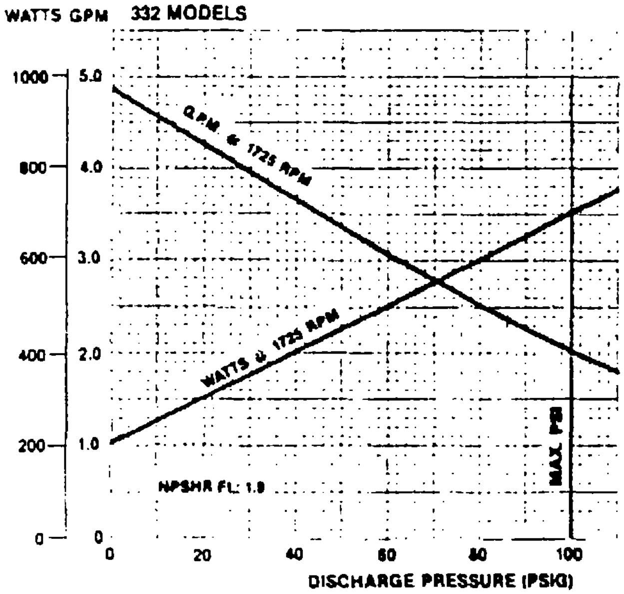
COMPONENT	MODELS			
	33159, 33259 33359, 34459	33160, 33260 33360, 34460	33152, 33252 33352, 34452	33150, 33250 33350, 34450
Housing Rotor Stator	Cast iron 416 SS/CP NBR (Nitrile)	Cast iron 416 SS/CP NBR (Nitrile)	316SS 316 SS/CP NBR (Nitrile)	316SS 316 SS/CP NBR (Nitrile)
Motor Data	1/2 HP,1 PH 115/230 VAC 60 HZ TEFC	1/2 HP, 3 PH 230/440 VAC 60 HZ TEFC	1/2 HP, 1 PH 115/230 VAC 60 HZ TEFC	1/2 HP, 3 PH 230/440 VAC 60 HZ TEFC
Weight (lbs)	41	41	41	41

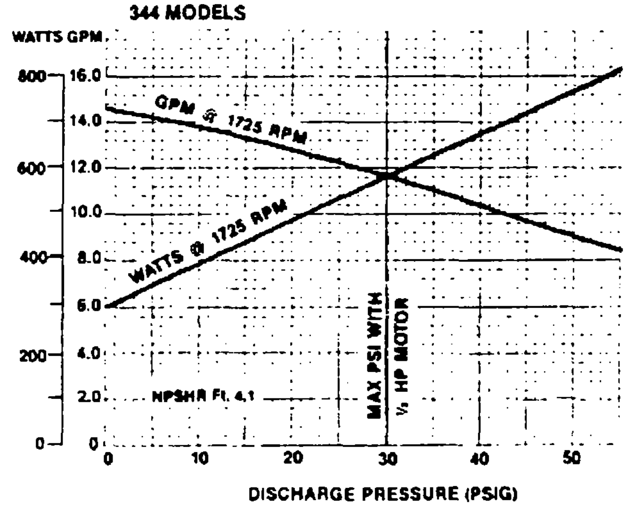
CP = Chrome plated

PERFORMANCE (Water at 70°F)









NOTE: With the standard 1/2 HP motor, maximum fluid viscosity is 100 CP (500 SSU).

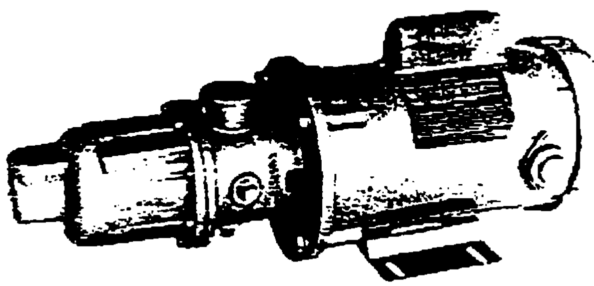
MOYNO

Always the Right Solution™

SERVICE MANUAL
MOYNO® 500 PUMPS
300 SERIES MOTORIZED
331, 332, 333, AND 344 MODELS

DESIGN FEATURES

Housing:	Cast iron/316 SS
Pump Rotor:	Chrome plated AISI 416 stainless steel/Chrome plated 316 stainless steel
Pump Stator:	NBR (Nitrile)
Seal:	Mechanical (carbon/ceramic)
Motor Shaft:	AISI 416 stainless steel/ANSI 316 stainless steel
Motor:	1/2 HP, 60 Hertz, 1725 rpm, totally enclosed, fan cooled (TEFC) C-Faced, 1 phase 115/230V or 3 phase 230/460V (other motor options available; consult sales representative)



Note: Alternate elastomers available. Refer to Repair/Conversion kit numbers pages 3 and 4.

INSTALLATION

Mounting Position. Pump may be mounted in any position. When mounting vertically, it is necessary to keep bearings above seals to prevent possible seal leakage into bearings.

Pre-Wetting. Prior to connecting pump, wet pump elements and mechanical seal by adding fluid to be pumped into suction and discharge ports. Turn pump over several times in a clockwise direction to work fluid into pump elements.

Piping. Piping to pump should be self-supporting to avoid excessive strain on pump housings. See Table 1 for suction and discharge port sizes of each pump model. Use pipe "dope" or tape to facilitate disassembly and to provide seal on pipe connections.

Electrical. Follow the wiring diagram on the motor nameplate or inside the terminal box for the proper connections. The wiring should be direct and conform to local electrical codes. Check power connections for proper voltage. Voltage variations must not exceed ±10% of nameplate voltage. Motor is provided with internal automatic overload protection.

To prevent damage to pump, pump rotation must be clockwise when facing pump from motor end.

OPERATION

Self-Priming. With wetted pumping elements, the pump is capable of 25 feet of suction lift with pipe size equal to port size. Be sure suction lines are air tight or pump will not self prime. Self-priming capabilities will vary due to fluid viscosity.

DO NOT RUN DRY. Unit depends on liquid pumped for lubrication. For proper lubrication, flow rate should be at least 10% of rated capacity.

Pressure and Temperature Limits. See Table 1 for maximum discharge pressure of each model. Unit is suitable for service at temperatures shown in Table 2.

Storage. Always drain pump for extended storage periods by removing bottom drain plug in pump body.

Caution: Suction pressure should never be greater than discharge pressure.

Table 1. Pump Data

Pump Model	Suction Port (NPT)	Discharge Port (NPT)	Voltage Rating (VAC)	Discharge Pressure (psig)
331	3/4	3/4	See Motor Name Plate For Voltage Ratings	150
332	3/4	3/4	See Motor Name Plate For Voltage Ratings	100
333	3/4	3/4	See Motor Name Plate For Voltage Ratings	50
344	3/4	3/4	See Motor Name Plate For Voltage Ratings	†30

†With 3/4 HP motor, pressure is 40 psig.

Table 2. Temperature Limits

Elastomer	Temperature Limits
*NBR	10°-160°F
*EPDM	10°-210°F
*FPM	10°-240°F

*NBR = Nitrile
EPDM = Ethylene-Propylene-Diene Terpolymer
FPM = Fluoroelastomer

TROUBLESHOOTING

WARNING: Before making adjustments, disconnect power source and thoroughly bleed pressure from system prior to disassembly. Failure to do so could lead to electric shock or serious bodily harm.

Failure To Pump.

1. Motor will not start: Check power supply. Voltage must be ± 10% of nameplate rating when motor is in locked rotor condition. Check for faulty capacitor on 1 phase Models.
2. Motor runs and thermally kicks out: Check for excessive discharge pressure. Check for defective centrifugal switch on 1 phase Models. Increase ventilation to motor. Do not use less than #14 wire size.
3. Stator torn; possible excessive pressure: Replace stator, check pressure at discharge port.
4. Flexible joint broken; possible excessive pressure: Replace joint, check pressure at discharge port.
5. Wrong rotation (3 phase only): Rotation must be clockwise when facing pump from motor end. Reverse the connections of any two line leads to the motor.
6. Excessive suction lift or vacuum.

Pump Overloads.

1. Excessive discharge pressure: Check pressure at discharge port for maximum ratings given in Table 1.
2. Fluid viscosity too high: Limit fluid viscosity to 100 CP or 500 SSU.

Noisy Operation.

1. Excessive suction lift or vacuum: Maximum suction lift is 25 feet for water.
2. Suction line too small: Check pipe size. Be sure lines are free from obstructions.
3. Pump Cavitates: Pump speed is 1725 rpm. Viscosity of fluid should not exceed 100 CP or 500 SSU.
4. Flexible joint worn: Replace joint. Check pressure at discharge port.
5. Insufficient mounting: Mount to be secure to a firm base. Vibration induced noise can be reduced by using mount pads and short sections of hose on suction and discharge ports.

Seal Leakage.

1. Leakage at startup: If leakage is slight, allow pump to run several hours to let faces run in.
2. Persistent seal leakage: Faces may be cracked from freezing or thermal shock. Replace seal.

Pump Will Not Prime.

1. Air leak on suction side: Check pipe connections.

PUMP DISASSEMBLY

WARNING: Before disassembling pump, disconnect power source and thoroughly bleed pressure from system. Failure to do so could result in electric shock or serious bodily harm.

1. Remove suction and discharge piping. Drain pump body by removing drain plug (261B).
2. Remove screws (112) holding suction housing (2) to discharge housing (1). Remove suction housing (2) and stator (21).
3. Remove rotor (22) from flexible joint (24) by turning counterclockwise (RH thread). On pinned, 3 phase models, remove rotor pin (45) with suitable punch.
4. Flexible joint (24) can be removed from motor shaft by using a 3/16 allen wrench in end of joint and turning counterclockwise. On 3 phase motors, remove motor pin (46) with suitable punch, then remove joint:
5. Slide mechanical seal (69) off motor shaft.
6. Remove discharge housing (1) from adaptor flange (12) by removing screws (1 12B).
7. Carefully pry seal seat out of discharge housing (1). If any parts of mechanical seal are worn or broken, the complete seal assembly should be replaced. Seal components are matched parts and are not *interchangeable.*
8. Remove adapter flange (12) from motor (70) by removing screws (112A).
9. *Remove slinger ring (77).*

PUMP ASSEMBLY

1. Install slinger ring (77).
2. Attach adaptor flange (12) to motor housing using screws (112A).
3. Attach discharge housing (1) to adaptor flange (12) using screws (1128). Be sure to center seal bore on shaft.
4. Install mechanical seal (69) in discharge housing (1) using the following procedure:
   a. Clean and oil sealing faces using clean oil (not grease).

Caution: Do not use oil on EPDM parts. Substitute glycerin or soap and water.

   b. Oil outer surfaces of the seal seat, and push assembly over the motor shaft and into the discharge *housing (1) seating it firmly and squarely.*
   c. After cleaning and oiling the shaft, slide the seal body along the motor shaft until it meets the seal seat.
   d. Install seal spring and spring retainer on shaft.
5. Thread flexible joint (24) into motor shaft in a clockwise direction (RH thread). Tighten with 3/16 allen wrench. On 3 phase models, install motor pin (46).
6. Thread rotor (22) onto flexible joint (24) in a clockwise direction (RH thread). On 3 phase models, install rotor pin (45).
7. Slide stator (21) on rotor (22). On 331 & 332 models, insert rounded end of stator ring (135) into end of stator prior to installing stator on rotor.
8. Secure stator (21) and suction housing (2) to discharge housing (1) using screws (112).
9. Lubricate rotor and stator by filling Suction housing and discharge housing with fluid to be pumped.
10. Connect Suction and discharge piping and power source.

PARTS LIST

To determine part numbers for all parts except standard motors, enter table with item number from pump illustration. Then locate part number under applicable model number (first three digits). Parts listed down the center are applicable to all pump models.
To determine part numbers for standard motor (item 70), enter table at item 70 with the last two digits of model number: motor description and part number are on that line.

Item No.	Description	Pump Model Numbers 331	332	333	344
1	Discharge Housing	Cast Iron 350-1016-000/Stainless Steel 350-1016-007			
2	Suction Housing	Cast Iron 330-1064-002/Stainless Steel 330-1911-002			
*21	Stator	340-3501-120	340-3502-120	340-3503-120	340-3504-120
*22	Rotor (Threaded) 416 S5	320-2729-000	330-0906-000	320-1394-000	320-1841-000
*22	Rotor (Pinned) 416 SS	320-2729-004	320-4559-004	320-1584-002	320-1569-002
24	Flexible Joint (Threaded)	Carbon Steel 320-1511-000/Stainless Steel 320-3759-000			
240	Flexible Joint (Pinned)	Carbon Steel 320-1612-000/Stainless Steel 320-4415-000			
*45	Shaft Pin (2 req.)	320-4069-002			
*69	Mechanical Seal	320-2424-000			
70	Standard Motor				
	-59 1PH TEFC 1750 RPM	330-4529-000			
	-60 3PH TEFC 1750 RPM, Pin	330-4528-100			
	-52 1PH TEFC 1750 RPM	330-4529-1 00			
	-50 3PH TEFC 1750 RPM	330-4528-003			
77	Slinger Ring	320-6382-000			
112	Screw, Cap (8 req.)	Carbon Steel 619-1430-103 (10-24 x 5/8)/Stainless Steel 619-1432-120 (10-24 x 3/4)			
112A	Screw, Hex Hd (4 req.)	Carbon Steel 619-1530-161 (3/8-16 x 1)/Stainless Steel 320-6715-005 (3/8-16 x 1)			
135	Stator Ring	Carbon Steel 320-7812-000 /Stainless Steel 362-1774-000			
215	Lock Washer (8 req.)	320-6464-000			
215A	Lock Washer (4 req.)	Carbon Steel 623-0010-411/Stainless Steel 320-6717-002			
261	Pipe Plug, 1/4 NPT	Carbon Steel 610-0120-021/Stainless Steel 610-0420-020			
	Rotor (Threaded) 316 SS	320-2933-000	320-2942-000	320-2936-000	320-2934-000
	Rotor (Pinned) 316 SS	320-2933-002			

*Recommended spare parts.
Used on 3 phase models.

REPAIR/CONVERSION KIT NUMBERS

Item No.	Description	All 331 Models (Threaded Only) NBR	EPDM	FPM	All 332 Models (Threaded Only) NBR	EPDM	FPM
—	Kit No.	311-9026-000	311-9025-000	311-9054-000	311-9027-000	311-9038-000	311-9055-000
21	• Stator	340-3501-120	340-3501-320	340-3501-520	340-3502-120	340-3502-320	340-3502-520
24	• Joint	*320-1511-000	320-6367-000	320-4670-000	*320-1511-000	320-6367-000	320-4670-000
69	• Seal	320-2424-000	320-6379-000	320-6501-000	320-2424-000	320-6379-000	320-6501-000

Item No.	Description	All 333 Models (Threaded Only) NBR	EPDM	FPM	All 344 Models (Threaded Only) NBR	EPDM	FPM
—	Kit No.	311-9029-000	311-9028-000	311-9056-000	311-9031-000	311-9030-000	311-9057-000
21	• Stator	340-3503-120	340-3503-320	340-3503-520	340-3504-120	340-3504-320	340-3504-520
24	• Joint	*320-1511-000	320-6367-000	320-4670-000	*320-1511-000	320-6367-000	320-4670-000
69	• Seal	320-2424-000	320-6379-000	320-6501-000	320-2424-000	320-6379-000	320-6501-000

NBR = Nitrile
EPDM = Ethylene-Propylene-Diene Terpolymer
FPM = Fluoroelastomer
*Carbon steel joint, for 316 SS joint use 320-3759-000.

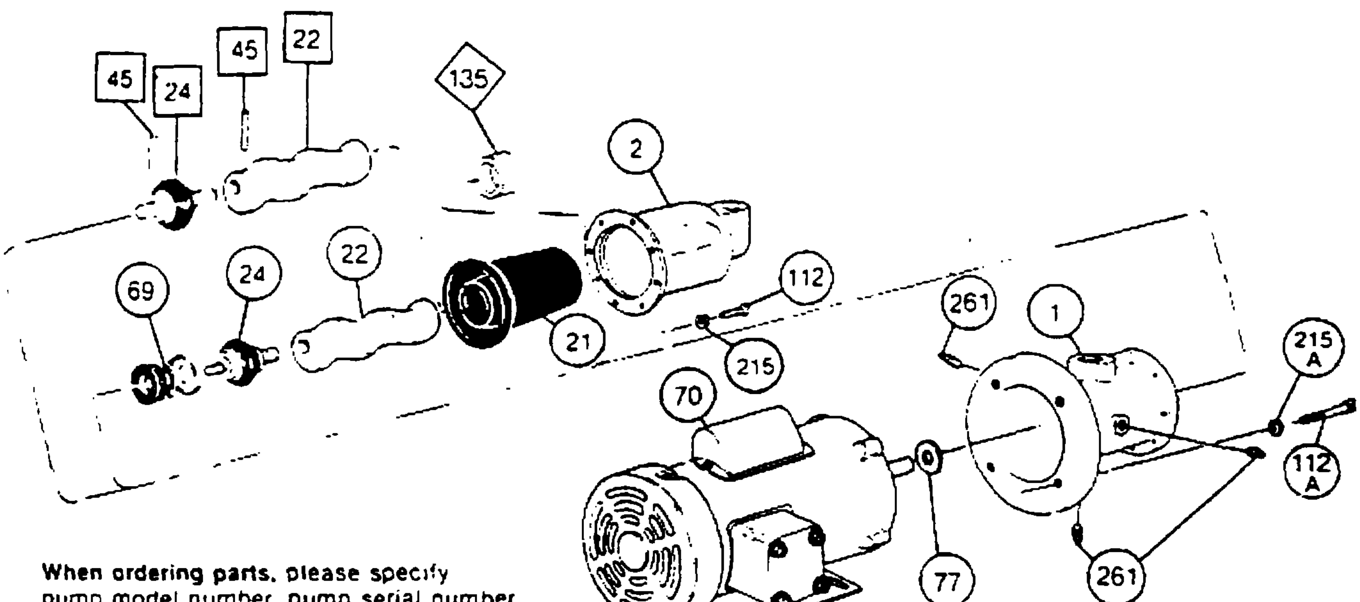
REPAIR/CONVERSION KIT NUMBERS (CONT.)

		All 331 Models (Pinned Only)			All 332 Models (Pinned Only)		
Item No.	Description	NBR	EPDM	FPM	NBR	EPDM	FPM
–	Kit No.	311-9104-000	311-9108-000	311-9112-000	311-9105-000	311-9109-000	311-9113-000
21	• Stator	340-3501-120	340-3501-320	340-3501-520	340-3502-120	340-3502-320	340-3502-520
24	• Joint	*320-1612-000	320-6973-000	320-6984-000	*320-1612-000	320-6973-000	320-6984-000
69	• Seal	320-2424.000	320-6379-000	320-6501-000	320-2424-000	320-6379-000	320-6501-000
45	• Pin (2 req.)	320-4069-002			320-4069-002		
		All 333 Models (Pinned Only)			All 344 Models (Pinned Only)		
Item No.	Description	NBR	EPDM	FPM	NBR	EPDM	FPM
–	• Kit No.	311-9106-000	311-9110-000	311-9114-000	311-9107-000	311-9111-000	311-9115-000
21	• Stator	340-3503-120	340-3503-320	340-3503-520	340-3504-120	340-3504-320	340-3504-520
24	• Joint	*320-1612-000	320-6973-000	320-6984-000	*320-1612-000	320-6973-000	320-6984-000
69	• Seal	320-2424-000	320-6379-000	320-6501-000	320-2424-000	320-6379-000	320-6501-000
45	Pin (2 req.)	320-4069-002			320-4069-002		

ABRASION RESISTANT SEALS

Elastomer	All 331 – 334 Models
NBR	320-6460-000
EPDM	320-6502-000
FPM	320-6503-000

NBR = Nitrile
EPDM = Ethylene-Propylene-Diene Terpolymer
FPM = Fluoroelastomer
*Carbon steel joint, for 316 SS joint use 320-4415-000.



When ordering parts, please specify pump model number, pump serial number, part number, part description and quantity.

◇ Used only on 331 & 332 Models.

□ Used on 3 Phase Models